Run Plan until 2020 Summer
&
Remaining Issues

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SuperKEKB workshop
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New Device for Next Operation

- LER crab waist operation mode
  - By spliting SLYTLP & SLYTRP magnet power supply
  - HER crab waist will be available during 2020 summar shutdown.
  - Single beam test to check beam storage stability and collision test to check beam-beam performance improvement are requried.
- LER D06V1 collimator
  - Background study & collimator tuning are required.

Run Plan until 2020 Summer

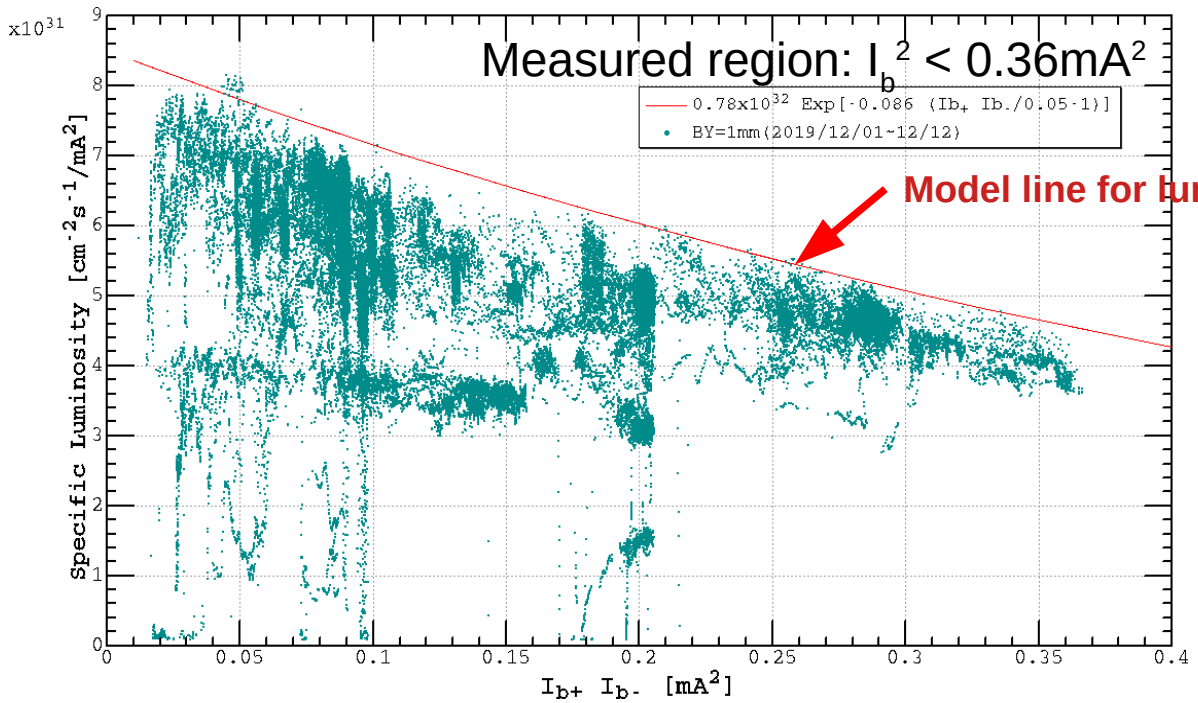
- 2020-02-25 ~ 2020-03-02 LER single ring operation
  - LER startup with detuned-optics
  - Vacuum scrubbing due to collimator installation works
  - BPM recalibration due to D06V1 collimator installation
  - (Single beam test for LER crab waist optics mode)
- 2020-03-02 ~ 2020-07-01 MR operation
  - First 3weeks assigns MR startup, reestablishment of collision operation and optics study.
    - 1st week – HER startup with detuned-optics, Hardware checking by storaged beam, Optics correction & β-squeezing
    - 2nd week – Optics-correction & β-squeezing(cont.), Collision/Luminosity tuning for reestablishiung 2019-12 collision performance
    - 3rd week – Extra XY-coupling correction study & Crab waist collision study
  - Remaining operation period is 14weeks + 2days(100days)
    - 11% of wall time is assigned to Linac study & regular maitenance.
      - ~1.5 shift / 1week for Linac study time
      - ~1.5 shift / 2weeks for regular maintenance & optics correction
    - Belle II group considers to use 1week in March for background study including D06V1 collimator tuning.

Luminosity Projection ~2020.07(1)

- Baseline performance from β^*_y=1mm operation during 2019-12-01 ~ 2019-12-12
  - Peak luminosity with detector data taking
    - 1.138 x 10^{34} (I=491.8/356.3mA, n_b= 783, I_b^2=0.286mA^2) @ 2019-12-07 05:03:35
    - 1.043 x 10^{34} (I=573.5/448.9mA, n_b=1565, I_b^2=0.105mA^2) @ 2019-12-11 01:32:47
  - Peak luminosity without detector
    - 1.879 x 10^{34} (I=819.2/639.6mA, n_b=1467, I_b^2=0.243mA^2) @ 2019-12-12 07:36:47
      - HER current was limited by effective injector power. (Low injection efficency due to BT end emittance larger than HER acceptance)
      - LER current was limited by confirmed stable storage current.
      - High repetition injection mode for both LER and HER is limited due to Linac bunch sheduling policy (especially for 4-ring injection case: MR + PF/PF-AR)
- Maximum stored beam current at β^*_y=1mm operation
  - HER 650mA
  - LER 880mA

Luminosity Projection ~2020.07(2)

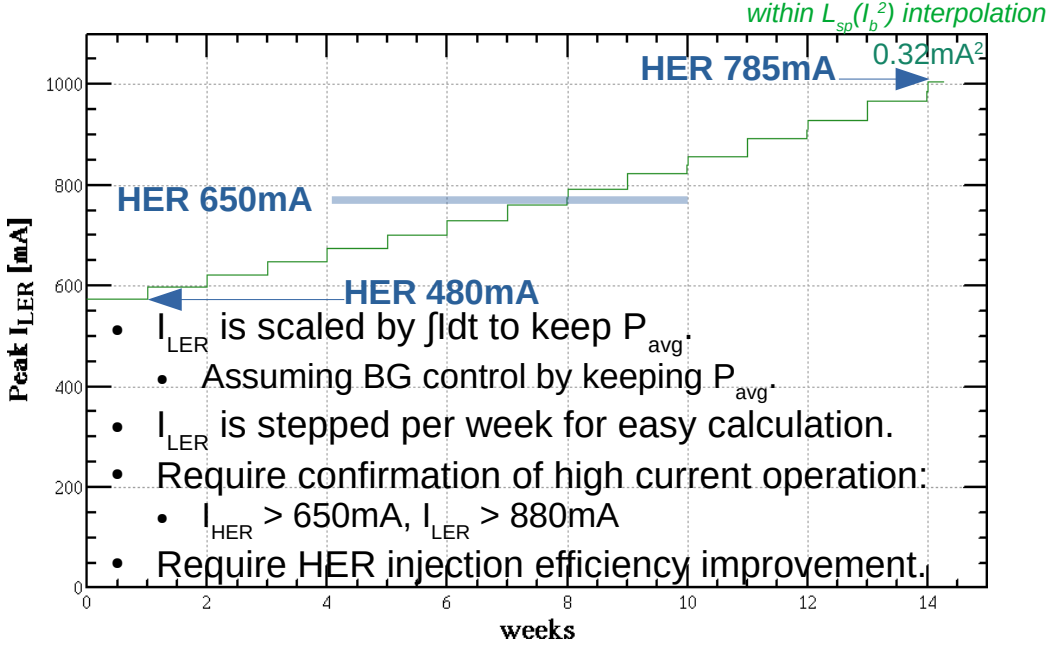
Bunch current product dependency of L_{sp} @ β^*_y=1mm collision



Luminosity Projection ~2020.07(3)

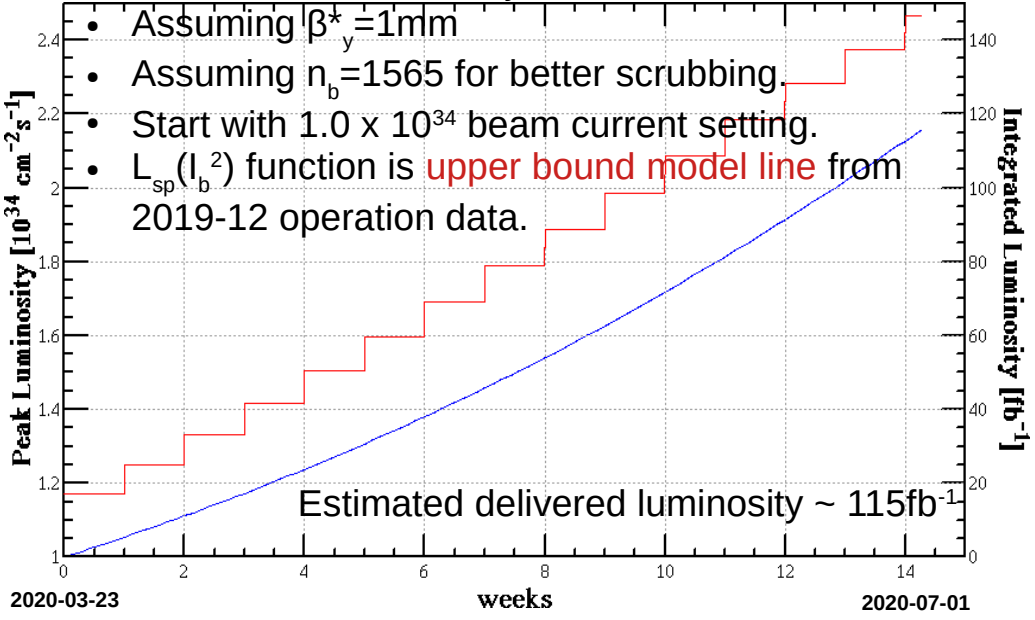
Estimation based on 2019-12 operation performance.

- **No extra beam-beam performance improvement is taken into account.**
- **No machine study time is taken into account.**



- I_{LER} is scaled by ∫Idt to keep P_{avg}.
  - Assuming BG control by keeping P_{avg}.
- I_{LER} is stepped per week for easy calculation.
- Require confirmation of high current operation:
  - I_{HER} > 650mA, I_{LER} > 880mA
- Require HER injection efficiency improvement.

- Integral efficiency 76%
  - Excluding Linac study & Maintenance 89%
  - Machine availability 85%



- Assuming β^*_y=1mm
- Assuming n_b=1565 for better scrubbing.
- Start with 1.0 x 10^{34} beam current setting.
- $L_{sp}(I_b^2)$ function is upper bound model line from 2019-12 operation data.

Luminosity Projection ~2020.07(4)

- Luminosity improvement posibilities in startup study:
  - Yet another coupling/dispersion correction
    - Expecting beam-beam parameter improvement by reducing IR local coupling/dispersion & IP chromatic coupling.
  - LER Crab Waist
    - Expecting beam-beam parameter improvement by reducing vertical waist mismatch by horizontal crossing angle.

Remaining Issues(1)

- **Low beam-beam parameter compared with expected one**
  - Beam physics group predicts big IP chromatic coupling and points out relationship between IP chromatic coupling and local coupling at SLY*.
  - Significant IP chromatic coupling is not clearly measured by COD based off-momentum coupling measurement.
    - We suspect lack of perturbation (momentum shift and orbit excitation are limited due to low β* optics) and measurement noise due to orbit drift during orbit measurements.
    - In order to control IP chromatic coupling at regular optics correction, we have to improve measurement method or to use another measurement method (e.g. TbT-BPM) to obtain good S/N measurement.
  - We plan study to try yet another coupling correction for interaction region during next run.
  - LER crab waist, which will try during next run, has posibility to improve beam-beam parameter.
- **Difficulty for achieving enough small vertical emittance by regular xy-coupling & v-dispersion correction sequence**
  - XRM vertical beam size growth is observed during correction itteration.
    - Skew quadrupole corrector parameter rollback recovers XRM beam size.
  - This issue will become more serious by squeezing β^*_y down to 300μm.
  - We suspect following possibilities and are trying to check its:
    - Effective excitation curve mismatch between skew quadrupole corrector winding on sextupole pair.
      - V-dispersion leakage mode measurement for xy-coupling mode excitation was tried, however, significant v-dispersion leakage is not observed.
    - Imperfection of -I cell between sextupole pair.
    - Inconsistency among 6-kind horizontal kick orbit responses due to orbit drift during response measurement.
      - Multiple xy-coupling measurements are performed on same optics and difference among orbit responses of same horizontal steering is observed.
      - One of workaround idea is data quality improvement by using statistics or searching model consistent data set from combination of multiple measurement. (Extra measurement time and evaluation function to optimize data combination are required.)

Remaining Issues(2)

- **Long tail of LER injection background time structure**
  - In order to reduce injection veto window, we have to understand mechanism of LER injection background time structure and to resolve it.
- **LER injection background spike**
  - This issue limits LER storage current to avoid Belle II CDC trip during data taking and its limit is hard compared with storage background limit now.
  - In order to improve LER current limit for data tacking operation, we have to understand mechnism of LER injection background spike and resolve it.
- **HER injection power limit**
  - BT charge limit (C/hour) interrupts HER full power injection for high current operation.
    - If charge limit is tripped, we have to wait next reset timing to restart injection.
    - Charge limit is tripped by integral ***transported*** charge.
  - Electron BT-end emittance at 2019 autumn run is not enough small compared with HER acceptance of β^*_y=1mm optics.
    - This situation will become more serious by squeezing β^*_y from 1mm down to 0.3mm.
  - In order to improve HER injection efficiency, smaller electron BT-end emittance is required.
    - Linac/BT transport tuning to preserve emittance and good initial beam quality of electron photo cathode gun are required.
    - Positron BT-end emittance was improved by correcting dispersion during previous run.
  - Electron photo cathode has been replaced during 2020-01.

Remaining Issues(3)

- **High bunch current operation stability**
  - Injectable betatron tune working area looks like shrinking by increasing bunch current.
  - KEKB achieves 1mA^2 bunch current product, however, we can not operate SuperKEKB beyond 0.4mA^2 bunch current product at this moment.
    - SuperKEKB design bunch current is 1.44mA x 1.04mA.
  - We have to survey tune working point or to try another sextupole setting, however, these will depend with IP β-function(ring optics).
- **IP collision feedback stability of slow iBumpFB software**
  - Beam-beam kick measurement value depends strongly with beam current.
    - Feedback target tracking is required during beam loss and recovery sequence.
  - Stepping by V-angle feedback seems shake beam-beam kick measurement value and excite V-offset oscillation.
    - Measurement results during iBump orbit transition may be used for feedback input.
  - Now fast iBumpFB and luminosity dithering based collision feedback are under developing.
    - Proof of concept is completed, however, additional developments are required to use for regular collision operation.
    - Dithering based collision feedback does not depend with beam-beam kick measurement.
  - We have to deploy new collision feedback system ASAP or to improve slow iBumpFB algorithm for stable operation.