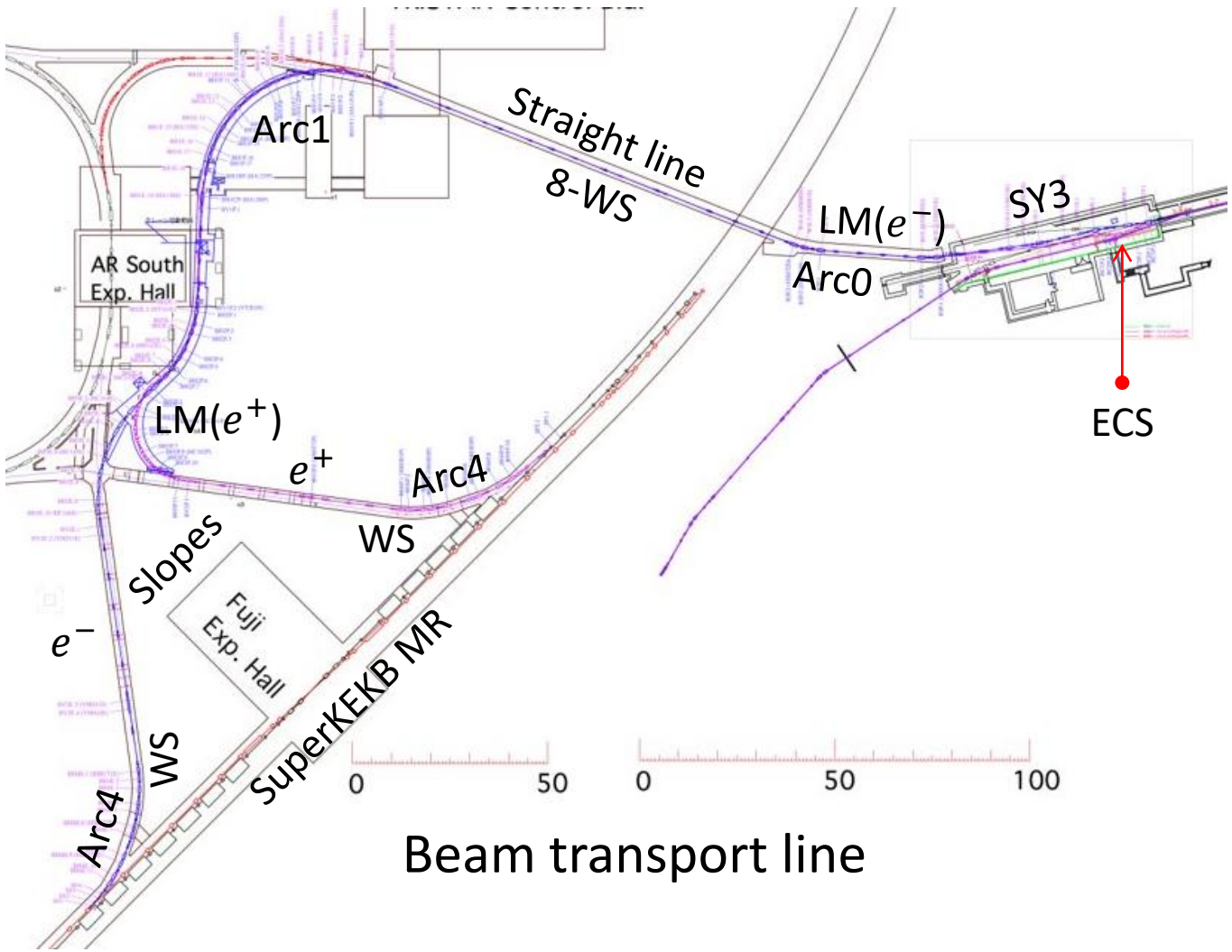
Status of beam transport lines

SuperKEKB review

2019.7.9

T. Mori, BT group

Contents



Beam transport line

- Modification for Phase-3
  - Septum leakage field suppression
  - Wire scanner (WS) update
  - Fiber loss monitor (LM) installation
- Issues found in Phase-3
  - DR extraction septum PS trouble
  - BPM
  - Rejection of Linac 1-pulse modulation
  - Emittance increase
- Future plan
  - Modification of radiation safety system for getting more Linac&BT study time
  - Construction of beam diagnostics line

Modification for Phase-3

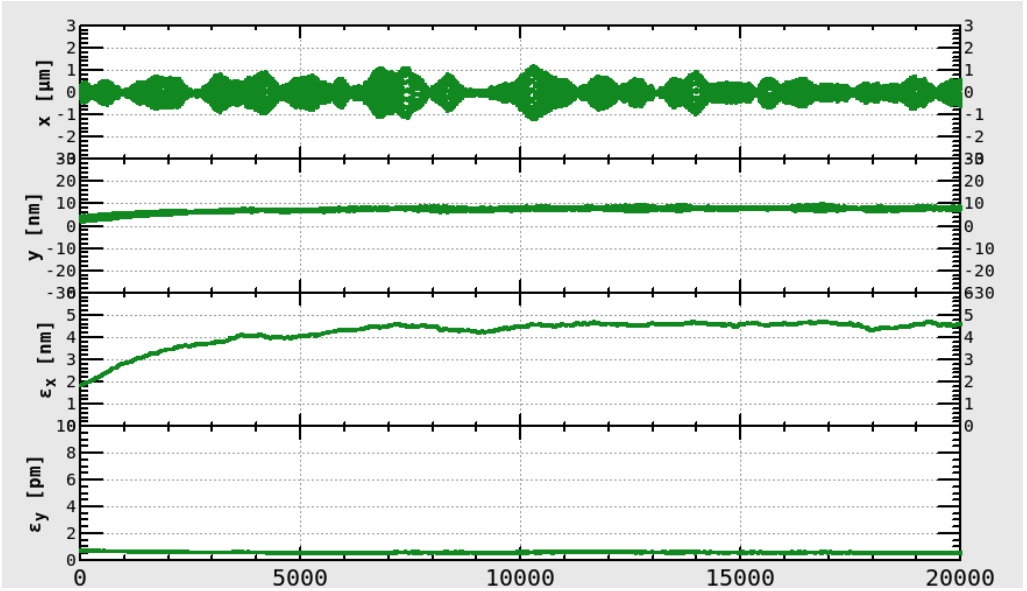
- Leakage field suppression for MR injection septum
- Wire scanner update
- Fiber loss monitor installation

Effect of septum leakage field

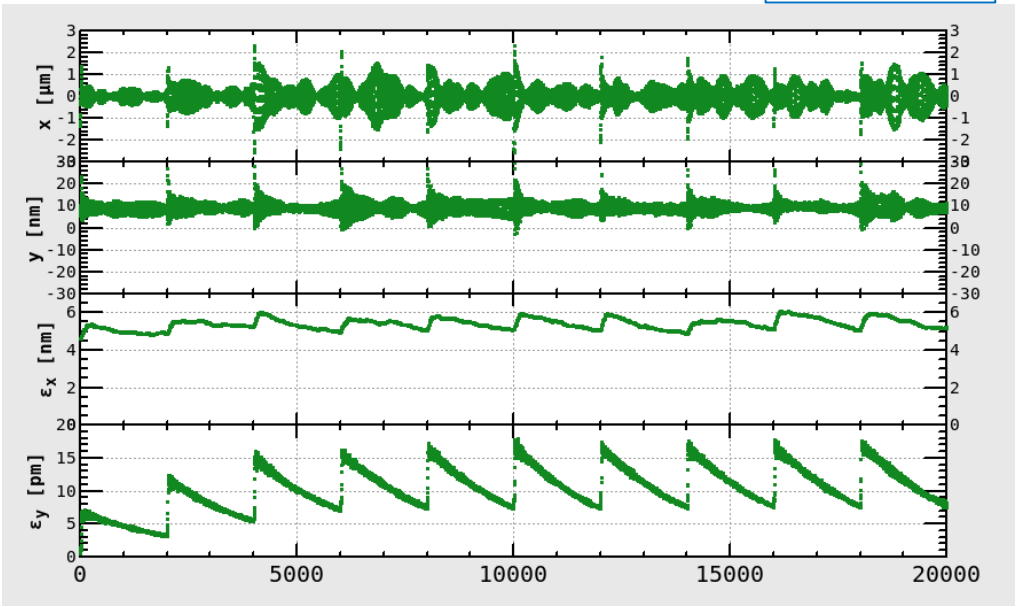
- It was found that septum leakage field from fringes might not be negligible for MR

LER (sler_1689.sad), 1000 positrons, 50 Hz injection, RFSW, RAD, FLUC, NOINTRA

Y. Ohnishi



Without leakage field from septum



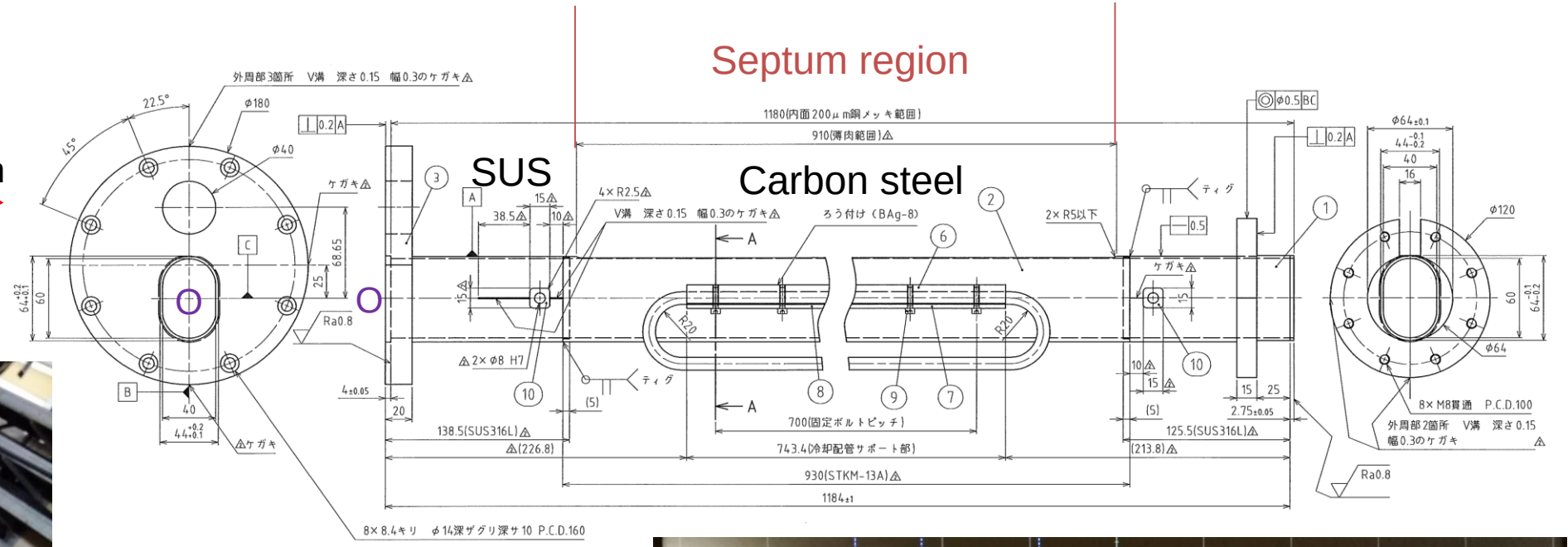
With leakage field from septum

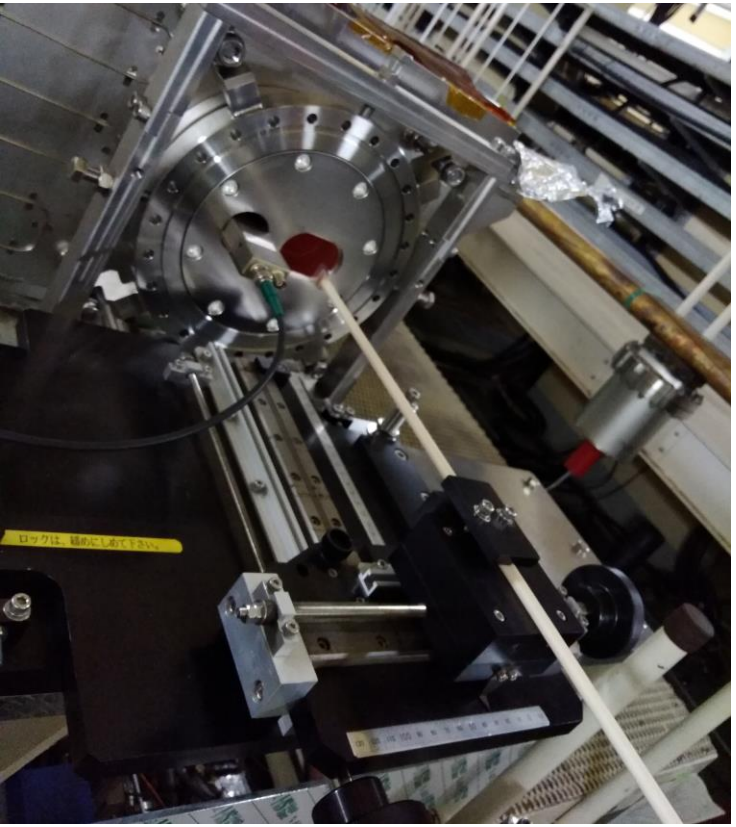
- Assumption for leakage: $BL \sim 1.0 \times 10^{-4}$ [Tm], $B'L \sim 0.014$ [T]

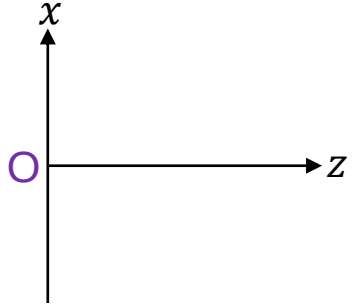
Septum leakage field measurement

Injection beam

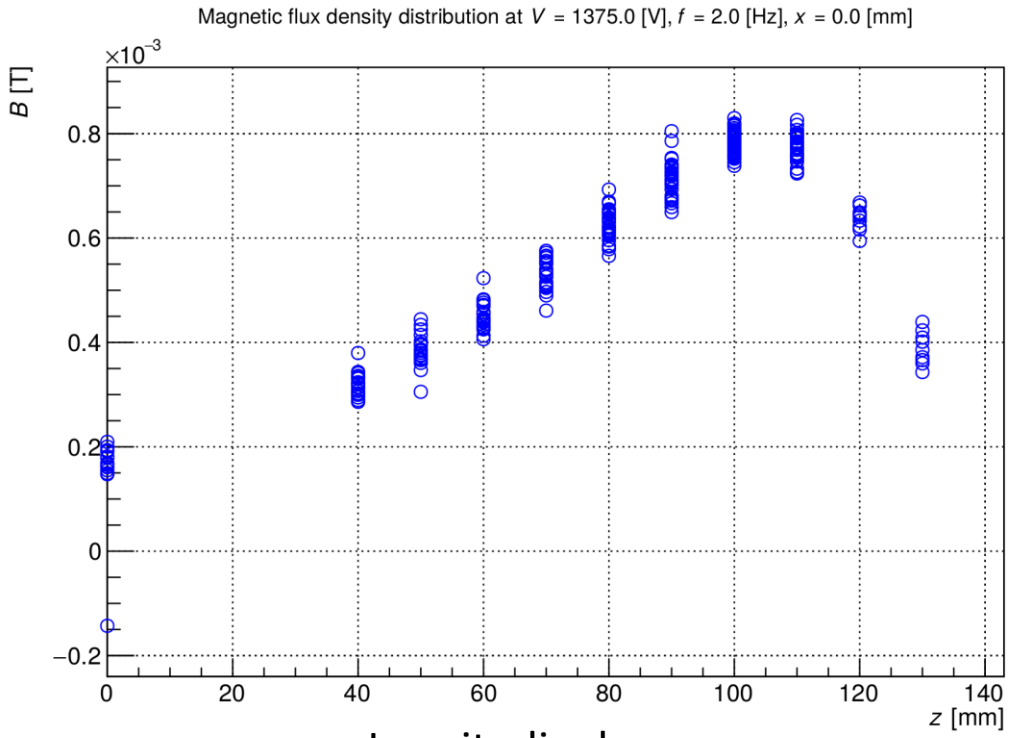
Stored beam



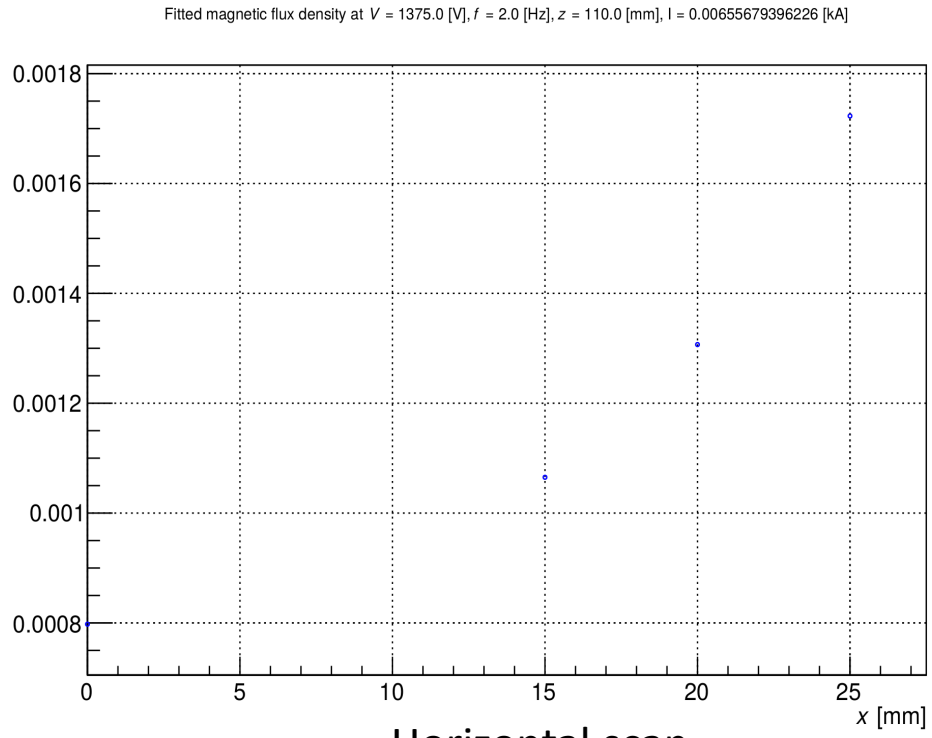




Septum leakage field measurement



Longitudinal scan

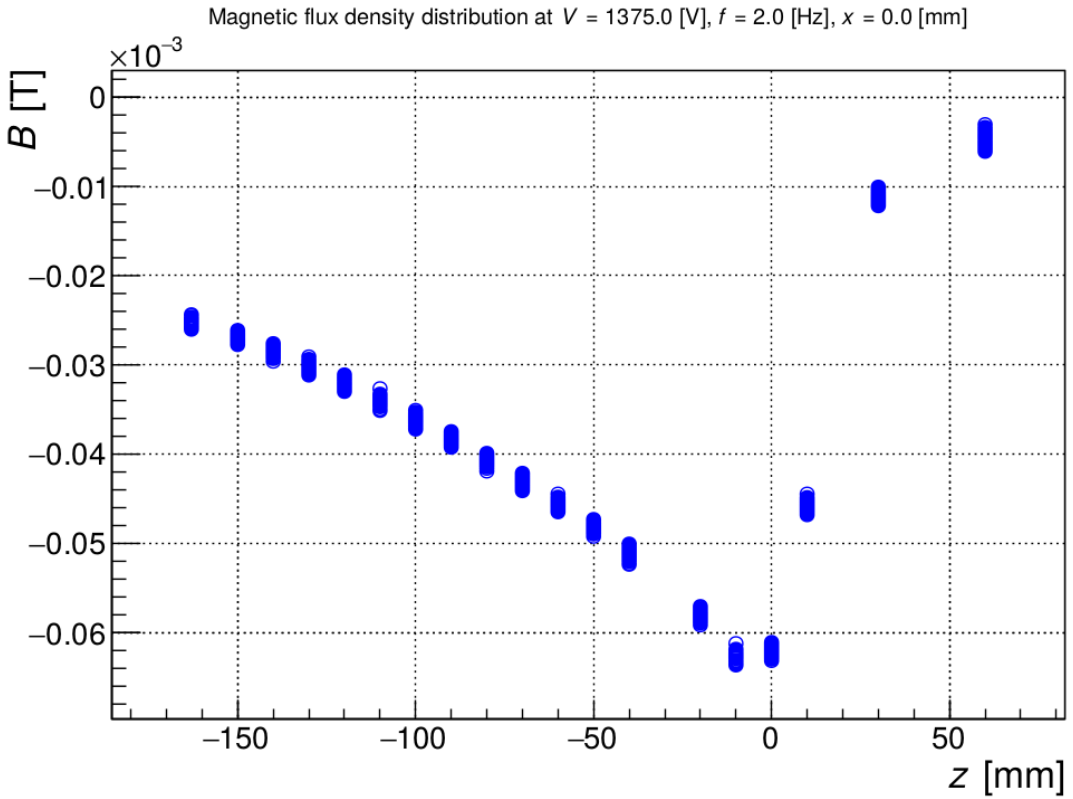


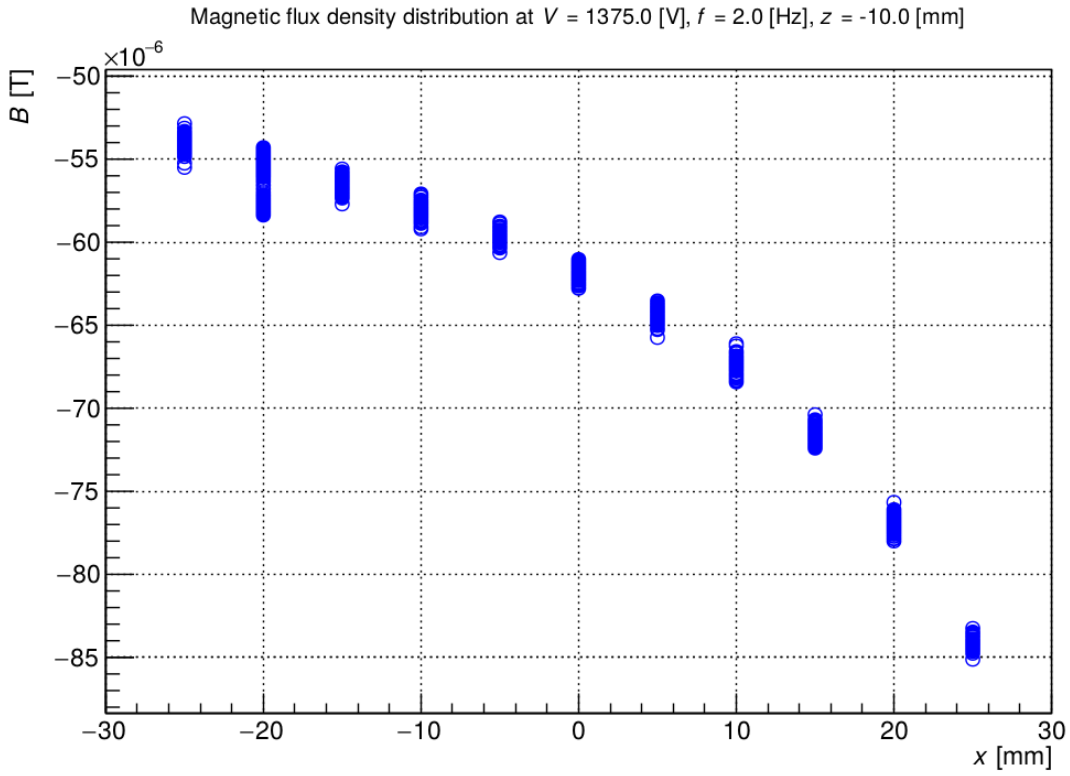
Horizontal scan

- $BL_{\max} \sim 2.8 \times 10^{-4}$ [Tm/fringe], $B'L_{\max} \sim 0.018$ [T/fringe]
- Both of LER/HER MR-ducts on septa was replaced with new ducts made of carbon steel overall

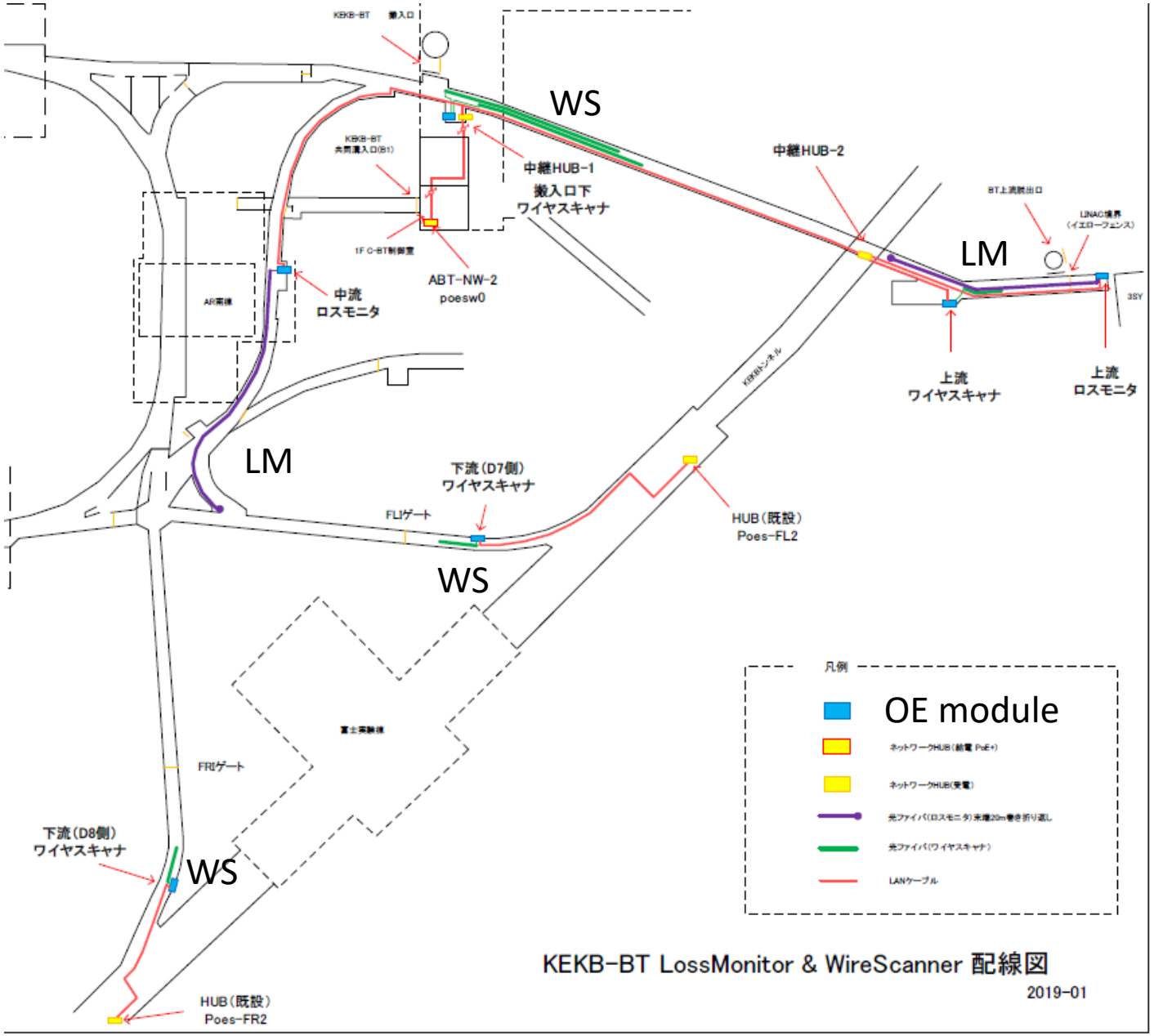
Vacuum group

Leakage field on new beam duct





- $BL_{\max} \sim 1.35 \times 10^{-5}$ [Tm/fringe], $B'L_{\max} \sim 0.0006$ [T/fringe]
  - 20 times smaller than that of previous measurement
  - If it not enough, there is the way that the beam duct wrapped by magnetic shield

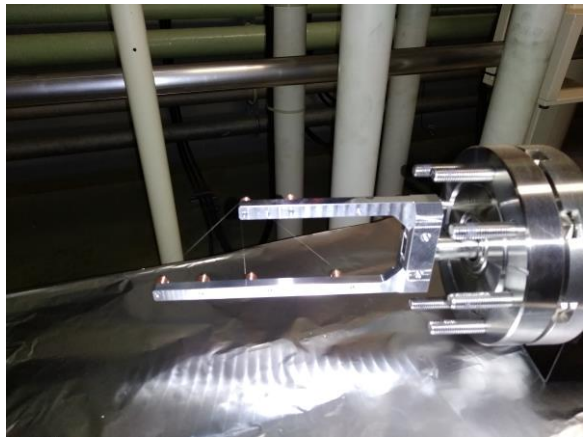


Fiber installation

- Fibers for WS and LM
- LM: both sides connected to OE module
- WS: single side connected to OE module, opposite side is blank

Wire scanner update

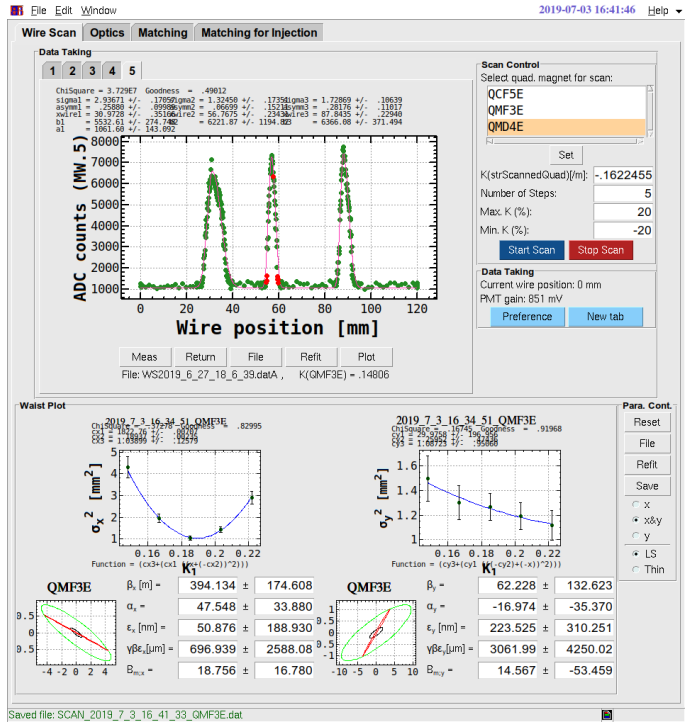
Wiring jig



Wire scanner is tilted by 45 degrees from a horizontal plane

All the wires of 11 WSs were replaced

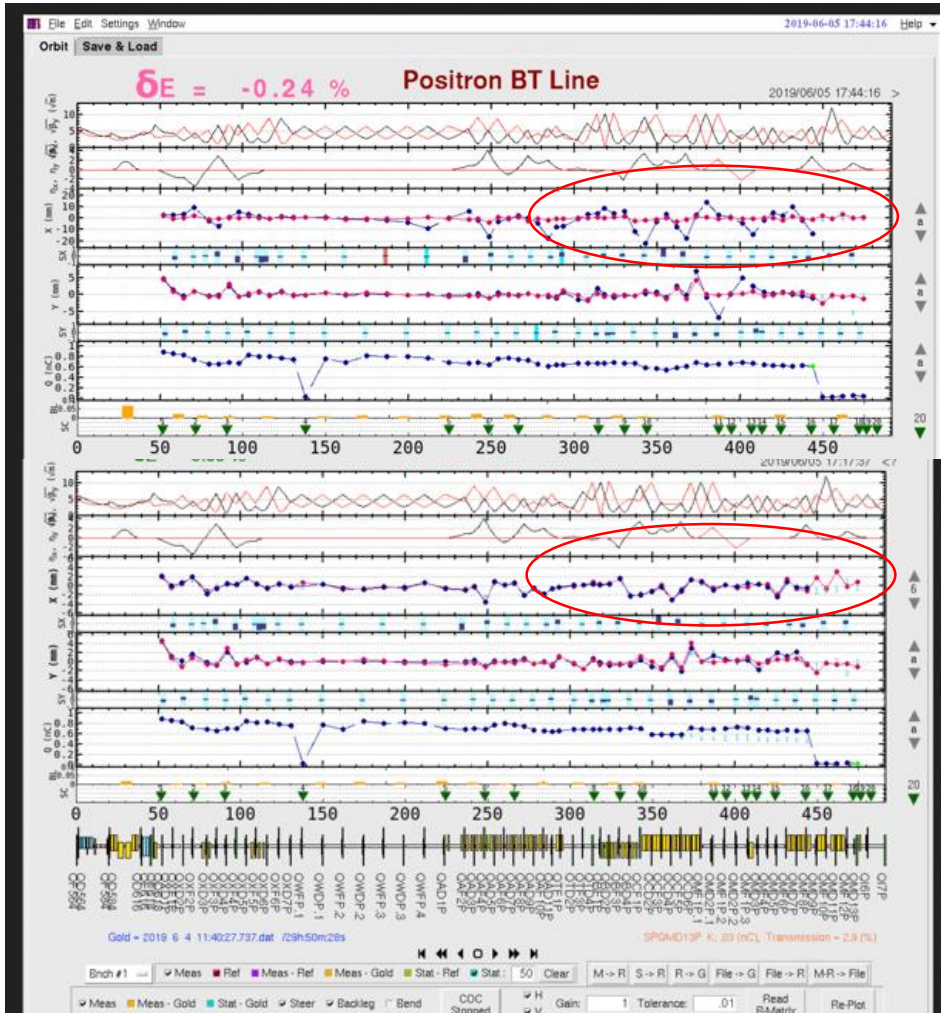
- Wire diameter: 200 → 60 μm
- Wire tension: 200 gf
- PMT → fiber loss monitor as detector
- DAQ system
  - VME event receiver, ADC, scaler
  - Pulsed motor controllers (LAN based connection)
  - Software updated

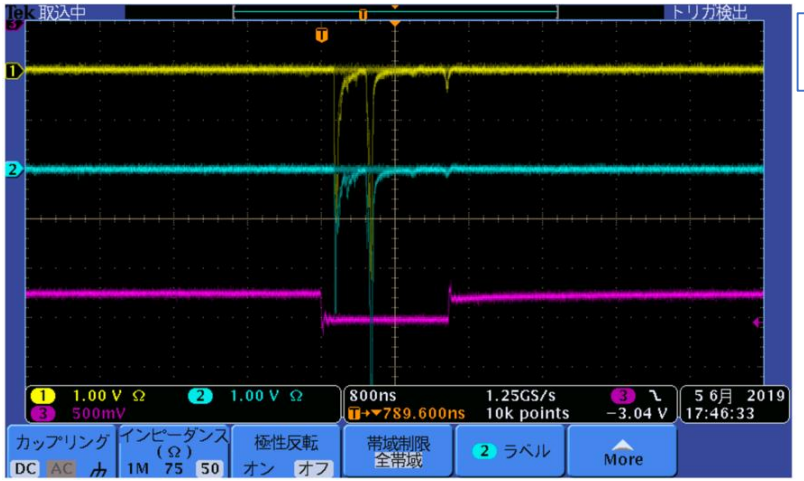


Beam loss measurement with fiber loss monitor

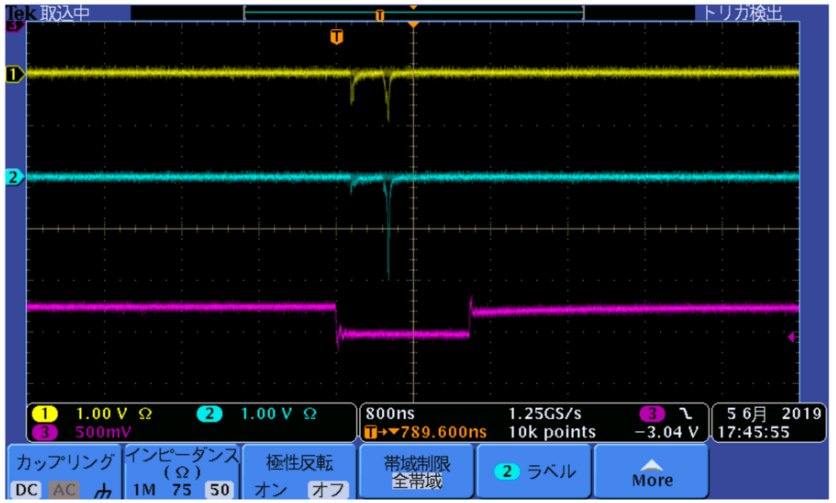
- Beam status
  - Electron: 1bunch 12.5Hz 0.7nC
  - Positron: 1bunch 12.5Hz 0.6nC
    5.85e-5 C/hour in total
  - N: 0.02 μSv/h, γ: BG @ BT escape door
  - N: 0.016 - 0.02 μSv/h, γ: BG @ ARS cable introducing port
- Currently 5.76E-4 C/hour is allowed by radiation safety; about 10 times larger
- 2-bunch, 25Hz, 2nC/bunch injection → 12 times larger if linearly scaled
- Loss rate should be kept less than threshold value

Fiber loss monitor





T. Mimashi



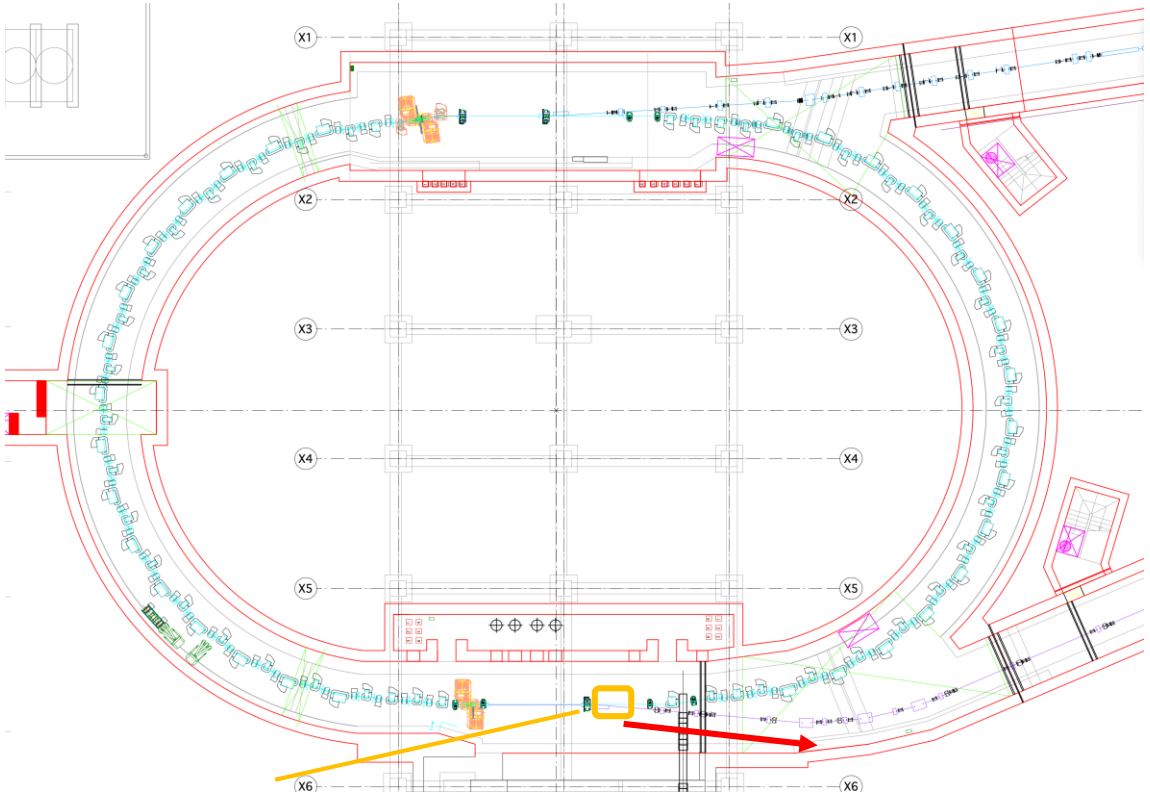
- Beam loss could be successfully reduced by BT orbit tuning
- Ready for 2-bunch, 25Hz, 2nC/bunch injection

Issues found in Phase-3

- DR extraction septum PS trouble
- BPM
- Rejection of Linac 1-pulse modulation
- Emittance increase
  - Will be reported in next presentation (N. Iida for Y. Seimiya)

DR Extraction Septum PS trouble

M. Tawada



DR extraction septum

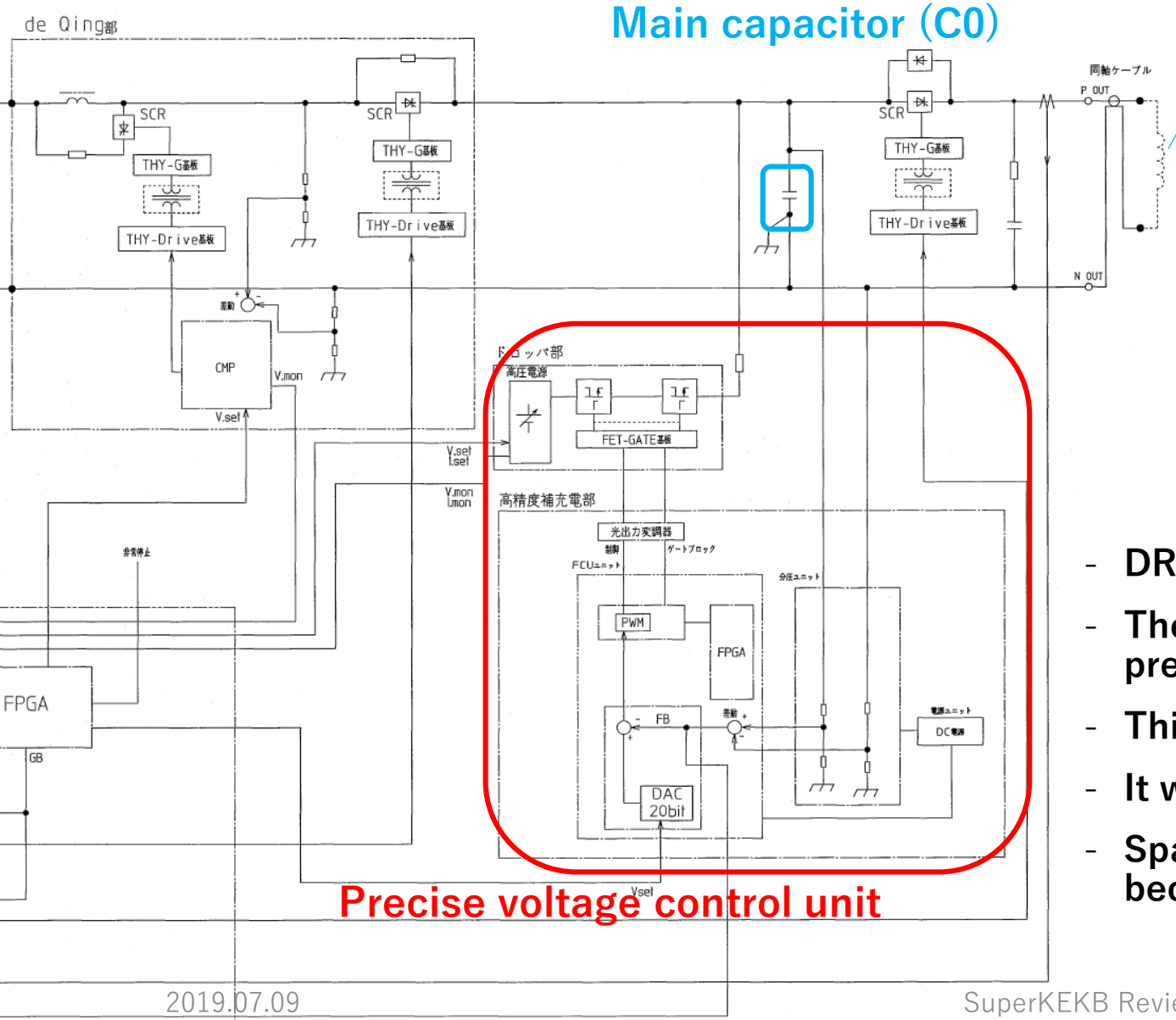
Deflection angle (mrad)	103
Max. current (kA)	12.5
Max. voltage (kV)	2.0
Voltage stability (%)	< ±0.01
Current waveform	full sine wave
Max. Repetition (Hz)	50
Full sin wave width(usec)	250
Magnet inductance (uH)	5.9

DR Extraction septum PS trouble

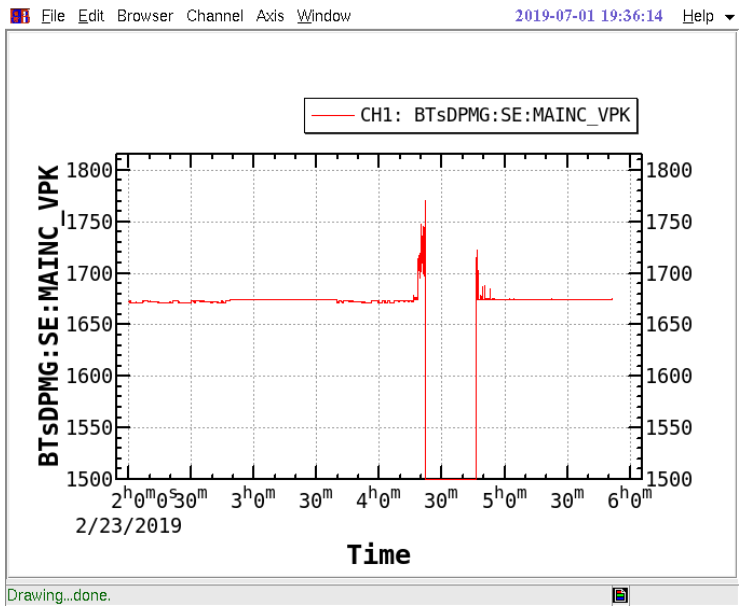
M. Tawada

Septum magnet

Main capacitor (C0)

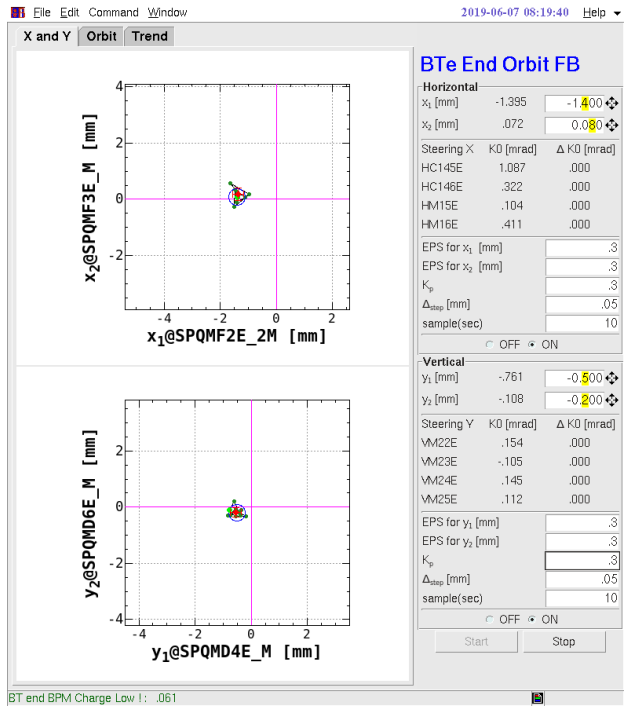


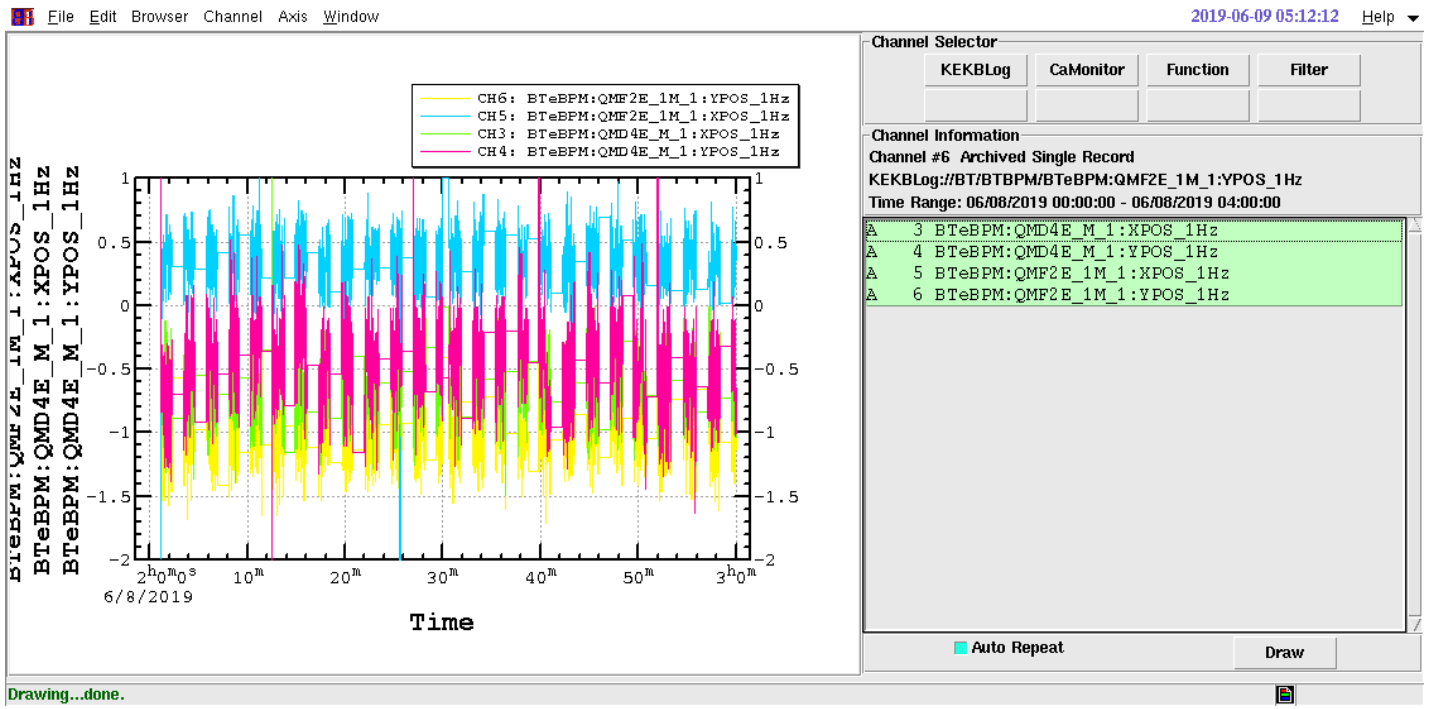
Precise voltage control unit



- DR extraction septum PS had been in trouble.
- The voltage of the main capacitor couldn't be controlled precisely.
- This failure had been disappeared during the investigation.
- It will be checked during this summer maintenance.
- Spare circuit board will be available in Jan. next year because of the global shortage of MLCC.

Issues for BPM: BT end feedback and bpm resolution





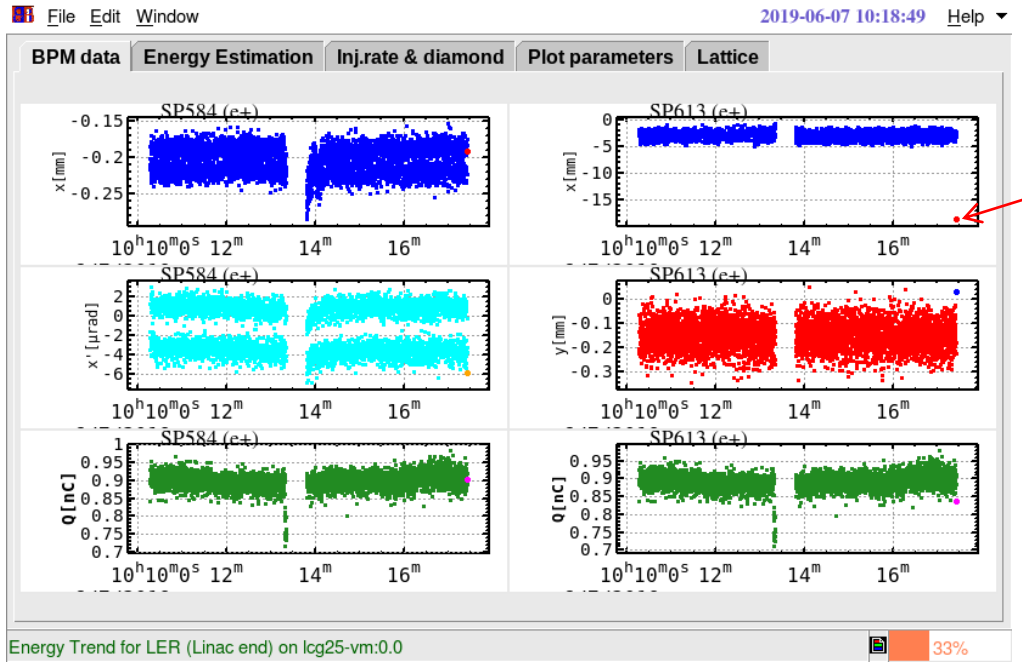
- Radius of target circle: 0.3 mm; larger target had induced beam abort
- Full width of BPM resolution: > 0.5 mm
- Asynchronous BPM readout: feedback delayed
- Difficult to keep orbit in target range

⇨ Maybe situation is severer for tighter MR optics

Issues for BPM

- Other problem
  - Old oscilloscopes (Windows XP) are still in use
  - ~10 channel of BPM signals combined and read by a oscilloscope channel
  - Installation of cables corresponding 1 to 1 BPM channel is difficult for budgetary restriction
- Solution under consideration
  - For BT end feedback (8-BPM): Libera
  - The rest of BPMs: Tektronix 12-bit ADC osc after command 'CURVESTREAM' implemented

Rejection of Linac 1-pulse modulation



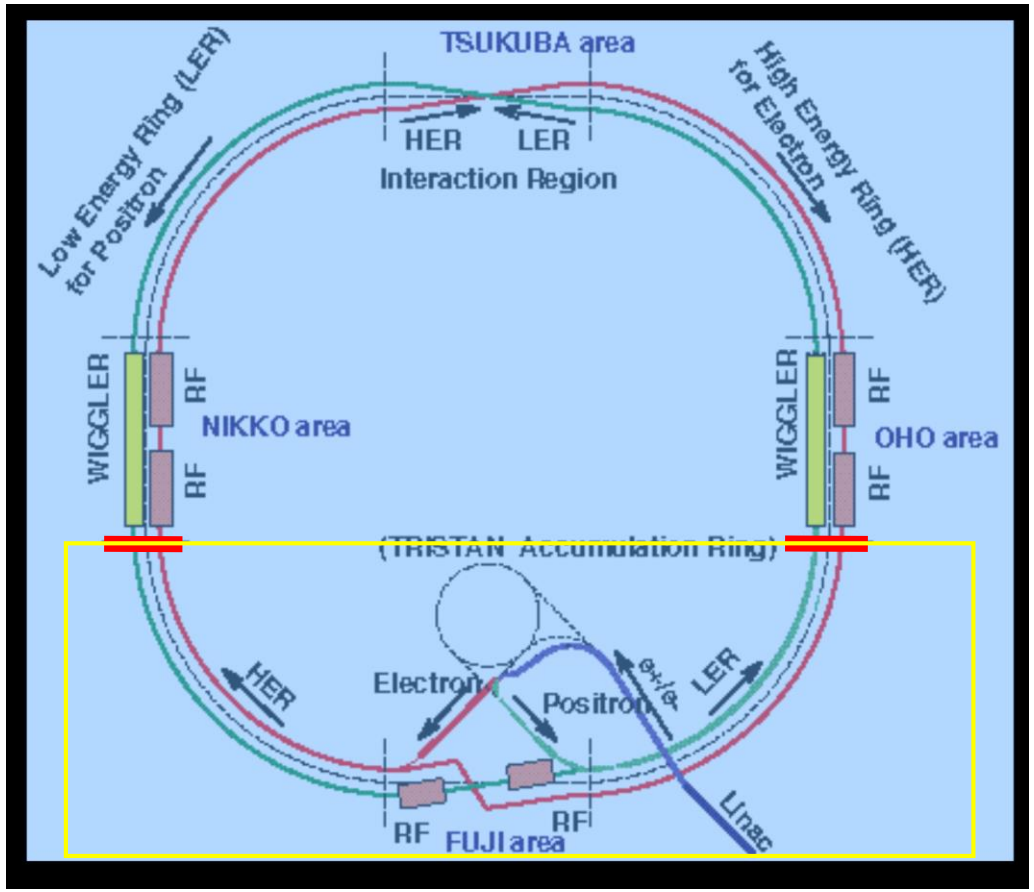
This type of beams induce MR abort

- Energy modulation ~ 50 Mev
- Impossible to reject modulated beams by collimators on BT-line
- Planning to relocation of collimators where dispersion exists
  - Middle of ECS@SY3 for positrons
  - Near vertical bend on end of slope for electrons

Future plan

- Modification of radiation safety system for getting more Linac&BT study time
- Construction of beam diagnostics line

Modification of radiation safety



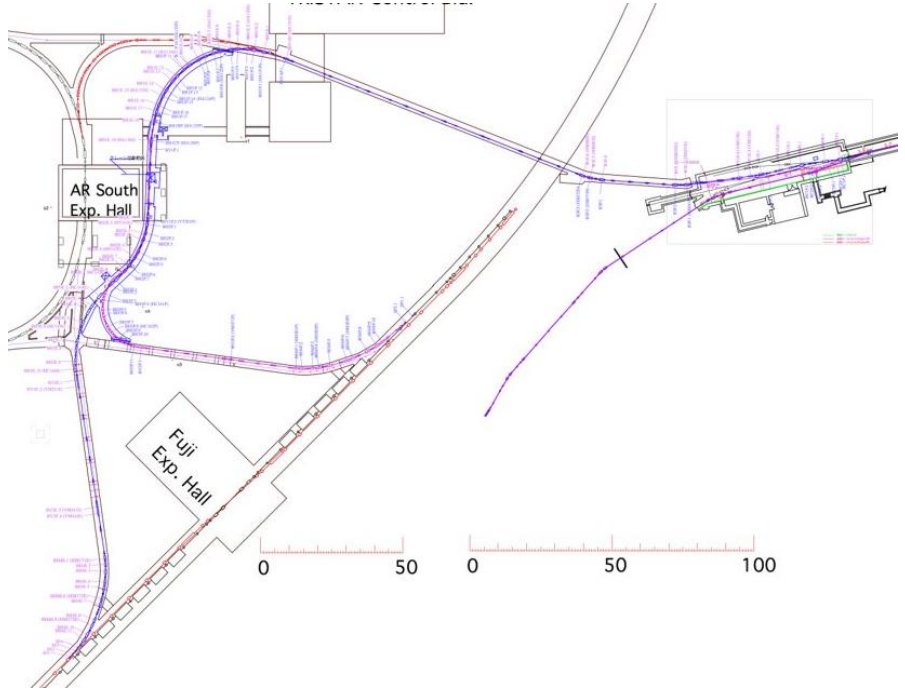
- Beam operation of BT is not allowed even if there are men only at opposite side of injection point (IR, BelleII)
- Divided management allows BT-dump mode operation when Tsukuba, Nikko, Oho is 'limit' or 'free' state
- Linac&BT need more study time
- Also important to reduce injection BG
- Task force organized, decided to do, detail specification development on going
- Fastest implementation: 2020 fall
- Safety is most important; we should be patient

Construction of beam diagnostics line

- Importance of keeping stable injection increases day by day
- Some people consider diagnostics system separately
- Task force will be organized

Summary

- Modification for Phase-3: successfully
  - Septum leakage field suppression
    - Overall carbon steel ducts were installed for LER/HER
  - Wire scanner
  - Fiber loss monitor installed
- Issues found in Phase-3: need breakthrough
  - Power supply trouble on DR extraction septum
    - Under investigation
  - BPM
    - Resolution and synchronization
    - Solution under consideration; Libera for BT-end feedback BPMs, 12-bit ADC osc for others
  - Rejection of Linac 1-pulse modulation
    - Collimator will be relocated to reject modulated beams
- Future plan
  - Modification of radiation safety system
    - Specific development on going
  - Construction of beam diagnostics line
    - Task force will be organized



Thank you

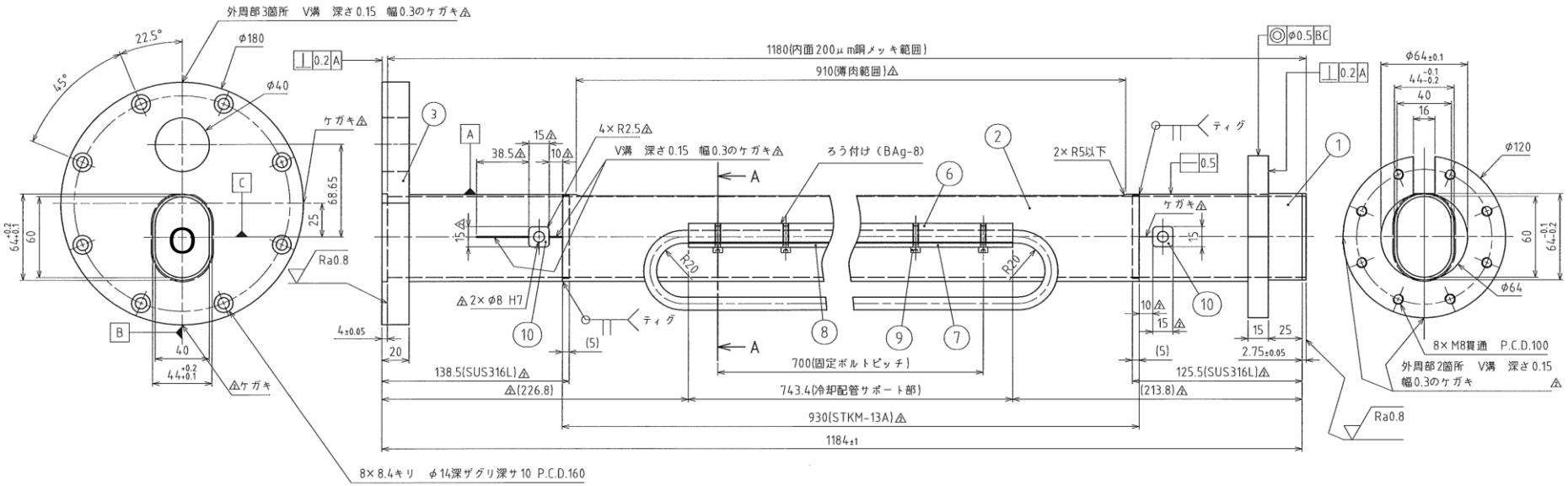
Backup slides

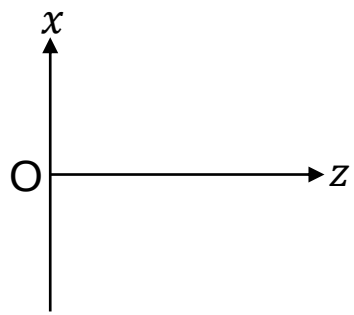
LER1 Septum Leakage Field

T. Mori

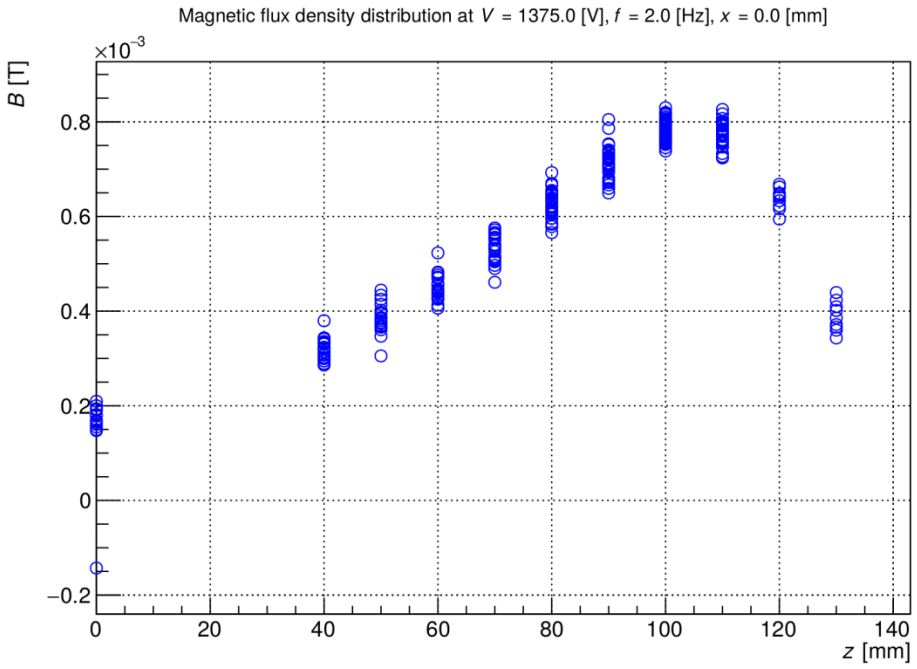
2017.11.06

測定方法

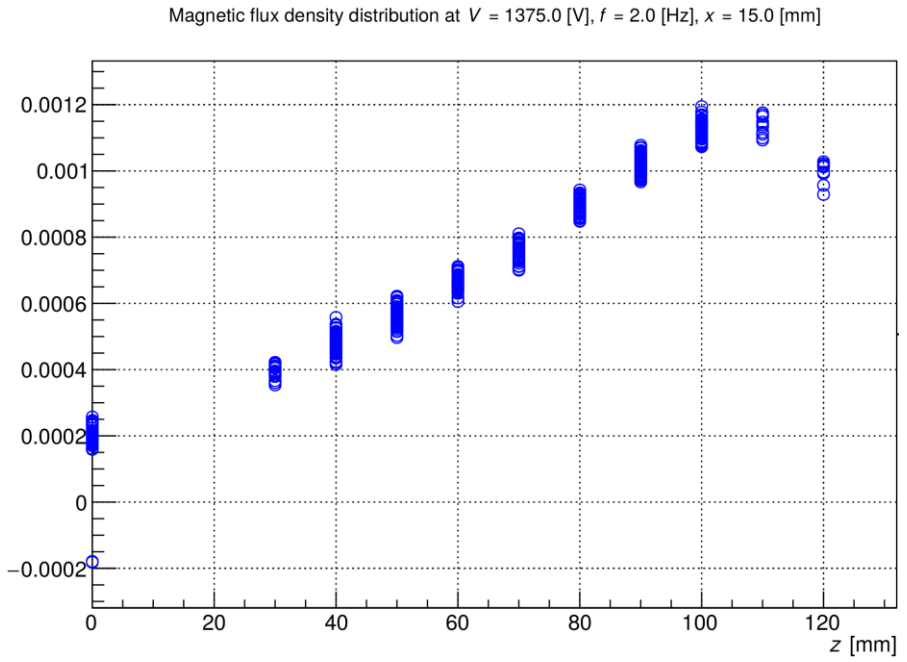

外周部3箇所　V溝　深さ0.15　幅0.3のケガキ
22.5°
45°
φ180
φ40
ケガキ
Ra0.8
8× 8.4キリ　φ14深ザグリ深サ10 P.C.160
1180(内面200μm銅メッキ範囲)
910(薄肉範囲)
4× R2.5
V溝　深さ0.15　幅0.3のケガキ
ろう付け（BAg-8）
2× R5以下
ティグ
2× φ8 H7
138.5(SUS316L)
(226.8)
700(固定ボルトピッチ)
743.4(冷却配管サポート部)
930(STKM-13A)
1184±1
125.5(SUS316L)
(213.8)
2.75±0.05
φ64
φ120
8× M8貫通　P.C.D.100
外周部2箇所　V溝　深さ0.15
幅0.3のケガキ
Ra0.8


x
O
z

z軸方向に測定

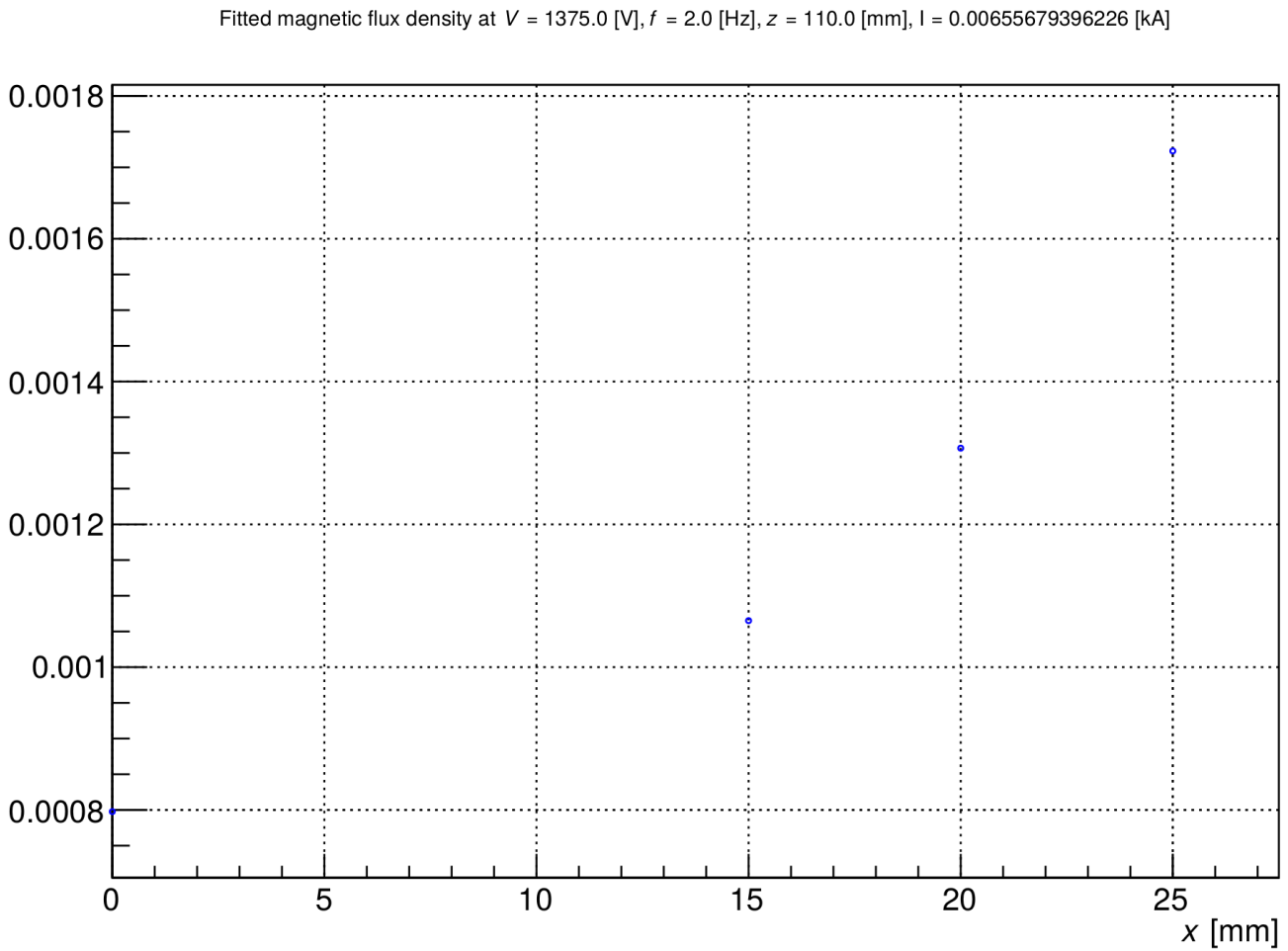


$x = 0.0[\mathrm{mm}]$



$x = 15.0[\mathrm{mm}]$

x軸方向に測定



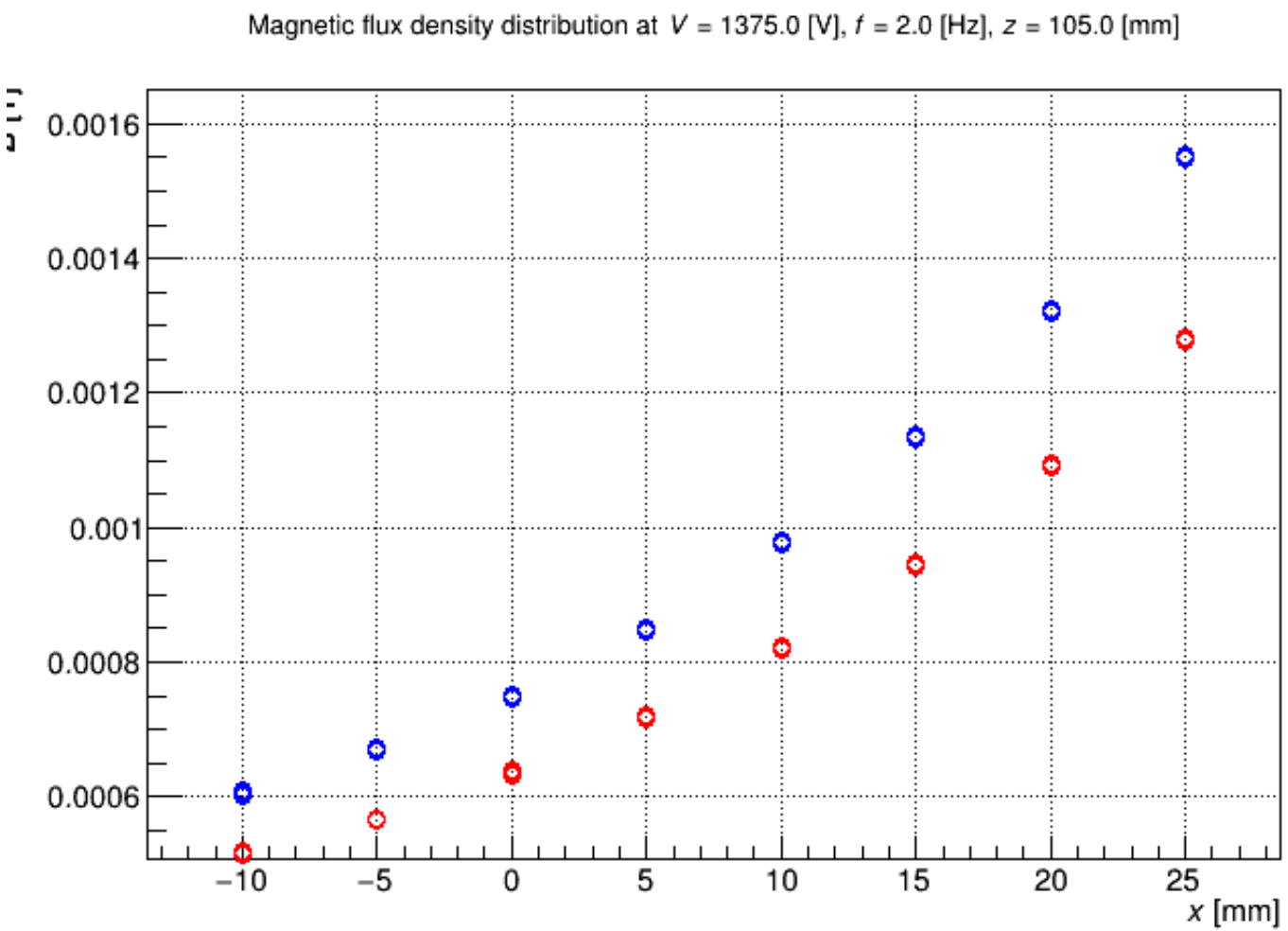
最大で20Gauss程度

$BL = 0.5 \times 0.28 \times 20 \times 10^{-4} = 2.8 \times 10^{-4}$[Tm]

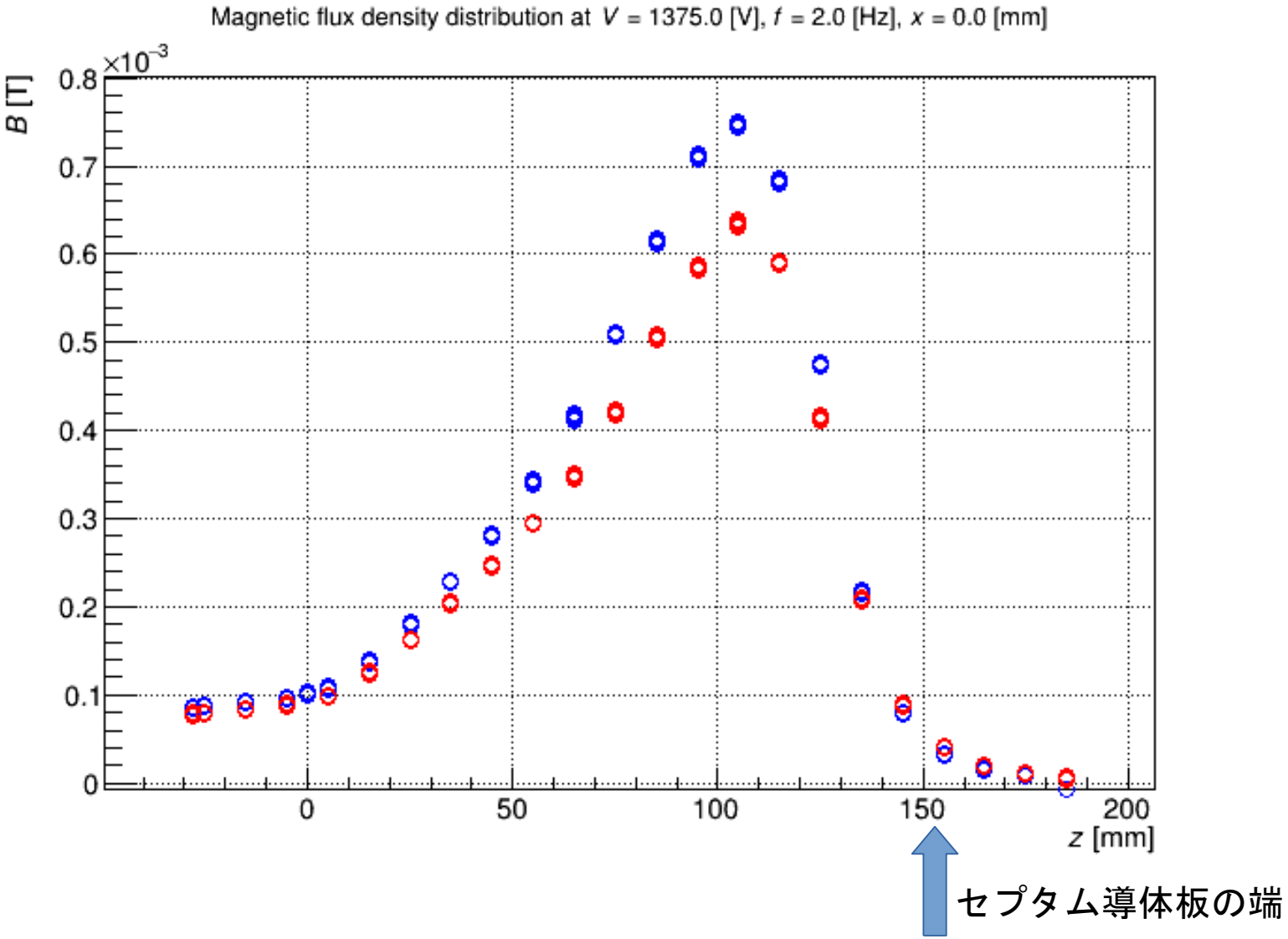
磁気遮蔽

- SUS430 filmを用意した
  - 2種類: 2 μm, 5 μm
- 5 μmはうまく巻けなかった
- 2 μmを巻いて、アルミテープで留めた
  - 本当は6 μm程度ほしいところ
  - 3枚くらい重ねて巻けばよかったかも？

SUS430-film あり/なし



SUS430-film あり/なし



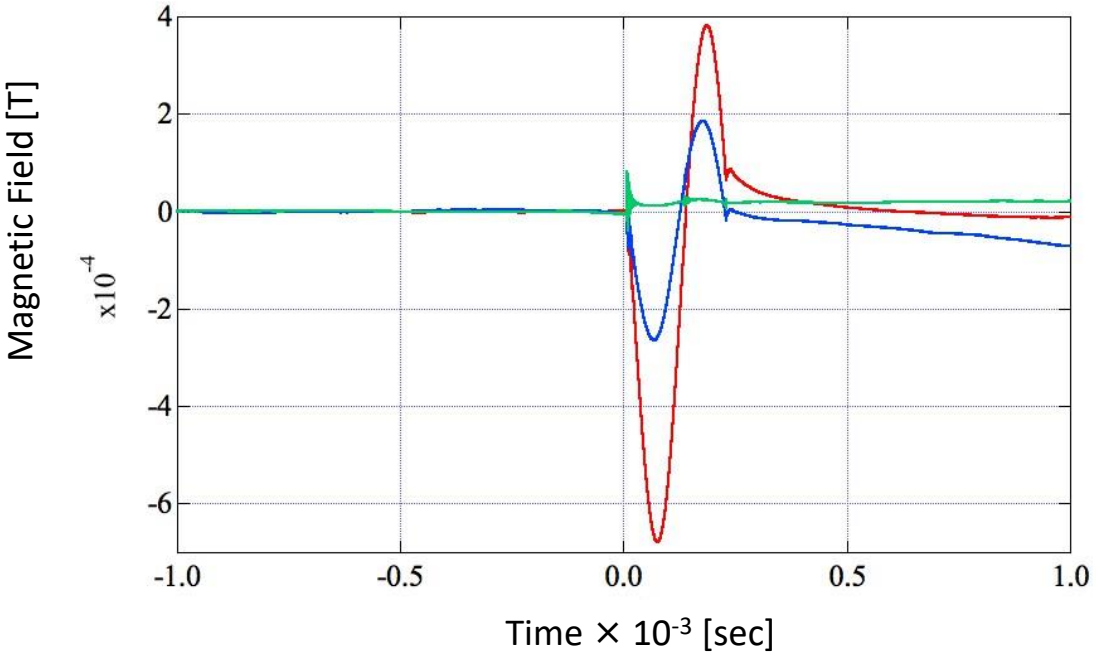
MR duct reproduction

- 作り直すとして、どのくらい磁性体部を延長するか
- D8側のMR ductも作り直すか
  - HER2部分
    - 磁性体にできるならしたほうが安心
      - 末次氏によると可能とのこと
  - 上流側短管
    - ここは磁性体のカバーを取り付ければよい
    - 作り直して入れる場合、上流側セプタムをどける必要がある

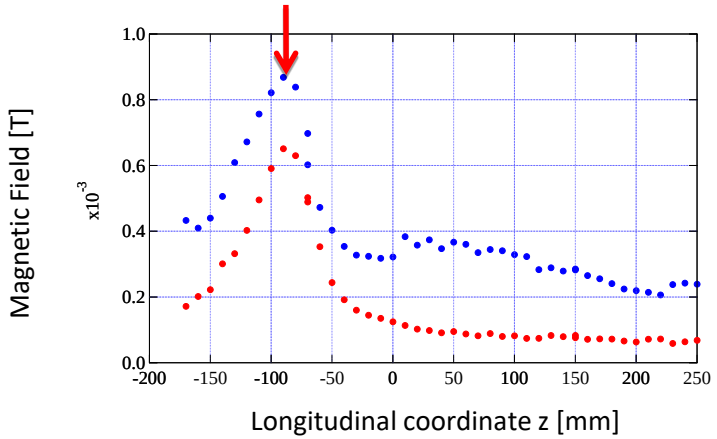
漏れ磁場：磁性体ダクト効果

小玉さんのスライドより

—：磁性体ダクトなし
—：磁性体ダクトをセプタム銅板端から25 mm突き出し
—：磁性体ダクトをセプタム銅板端から100 mm突き出し
（上流側の磁性体ダクト突き出し量）



もれ磁場が最大の場所で測定
(コア端から90 mm，セプタム板端から20 mm)

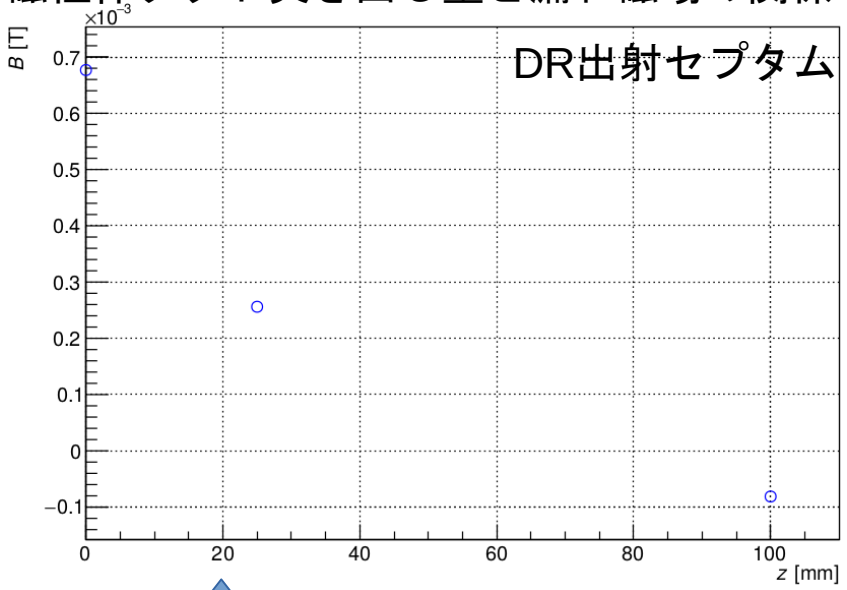


漏れ磁場は磁性体ダクトによって十分に小さい信号値まで減少.

*菊池さんの計算によると1 Gauss程度の磁場では周回ビームへの影響は少ない

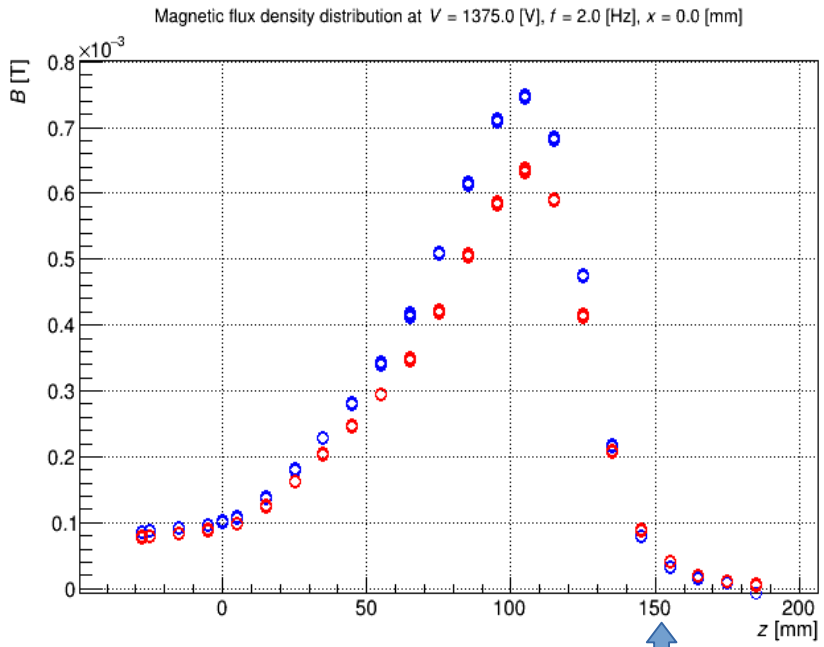
ダクト突き出し量と漏れ磁場

磁性体ダクト突き出し量と漏れ磁場の関係



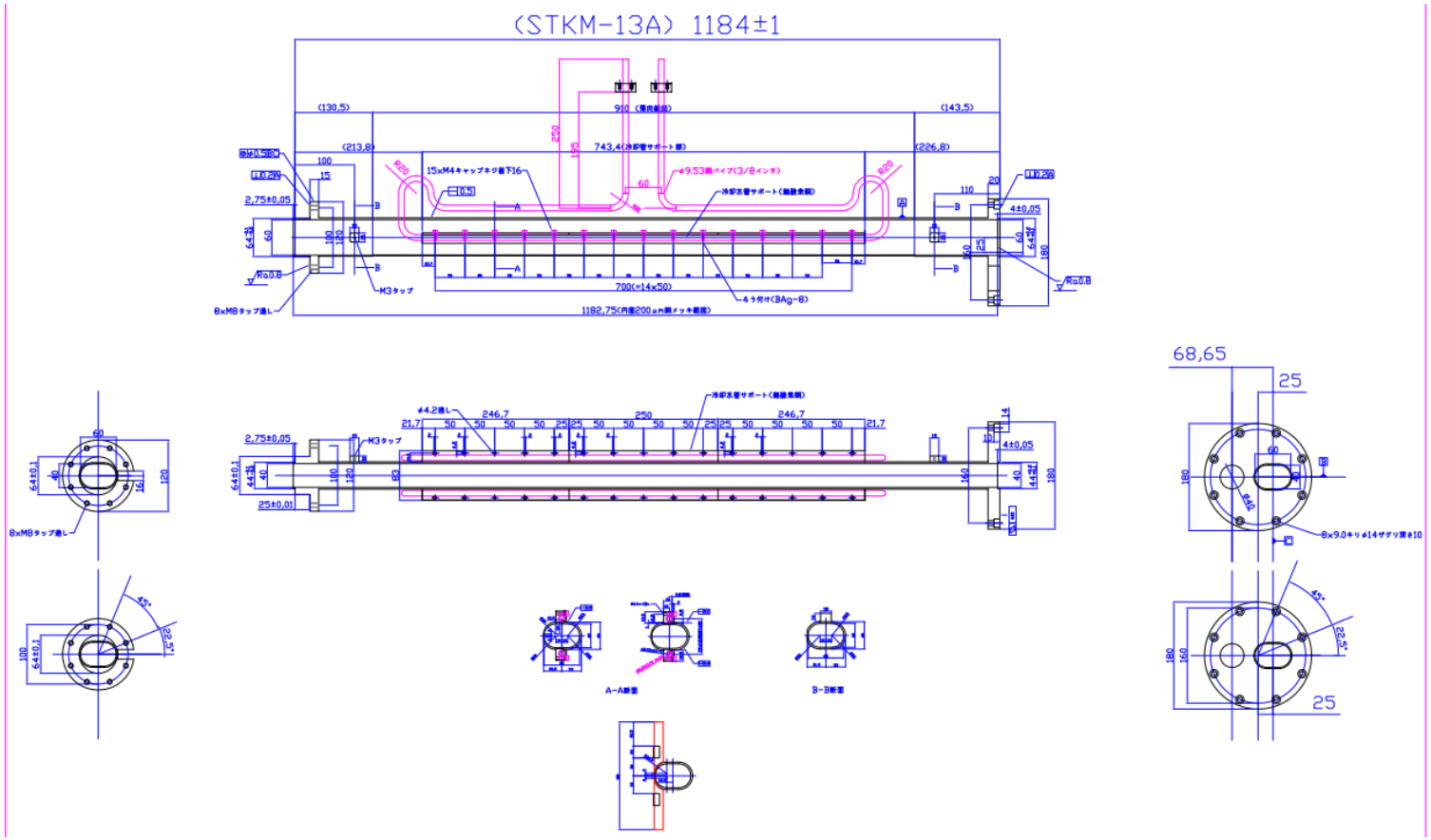
プローブの位置

- プローブの位置まで磁性体ダクトが来ていると半分程度に落ちる

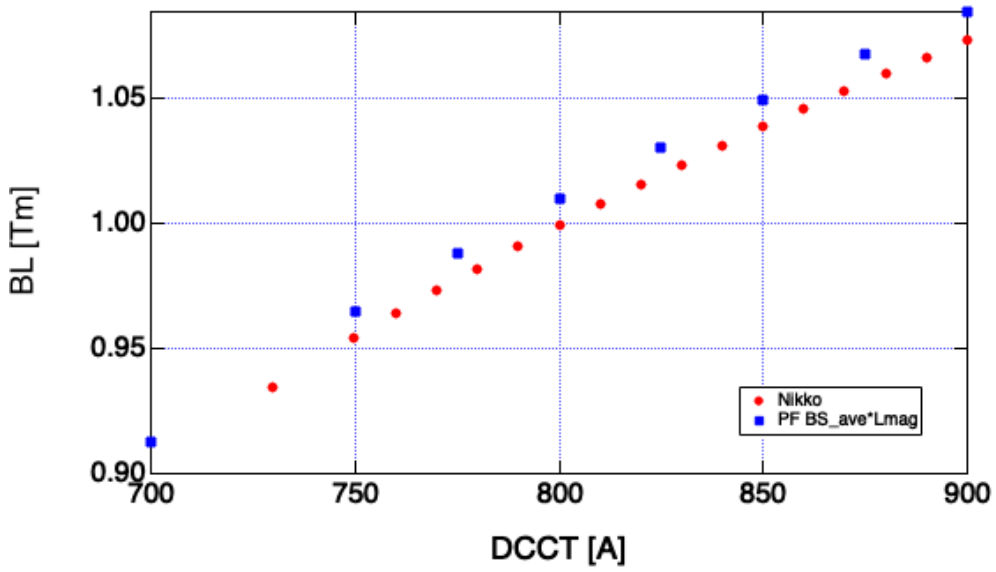


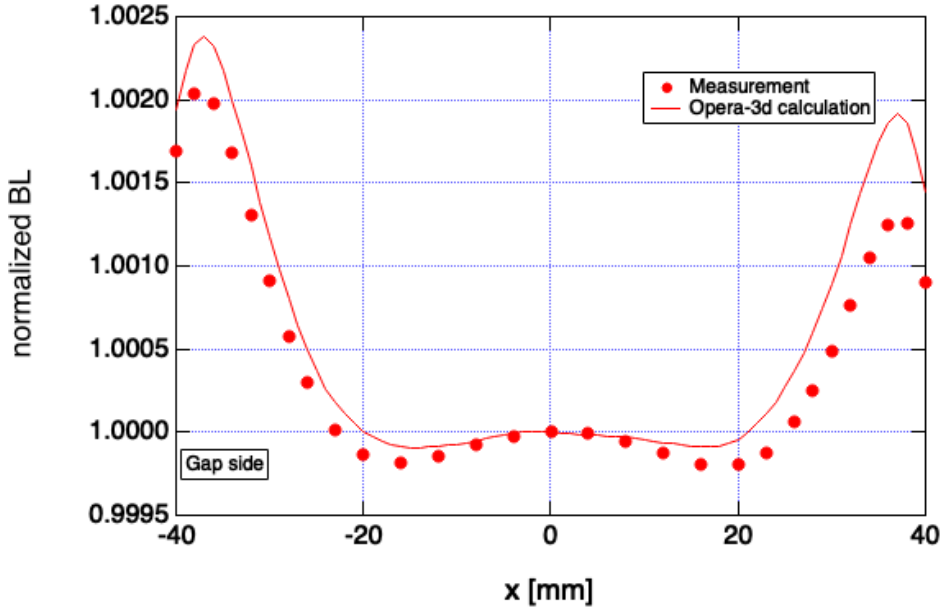
MRダクト磁性体部をセプタム導体板の端から150mm程度延ばす　セプタム導体板の端

Design of reproduced beam duct (LER)



R10.2: Cross-calibrate the field measurements of magnets between LTR, RTL, DR, and Linac.





IRトンネル入域中の BT dump mode化

2019.3.29

SuperKEKB Commissioning打ち合わせ

N. Iida

これは、MRの富士周辺のみをキープアウトにすることにより、筑波地区などリングの他の場所での作業中でも、BTラインでのビーム調整、ビームスタディを可能にするためにシステム変更をお願いしたいという趣旨に基づくものです。

船越 義裕 (KEK)

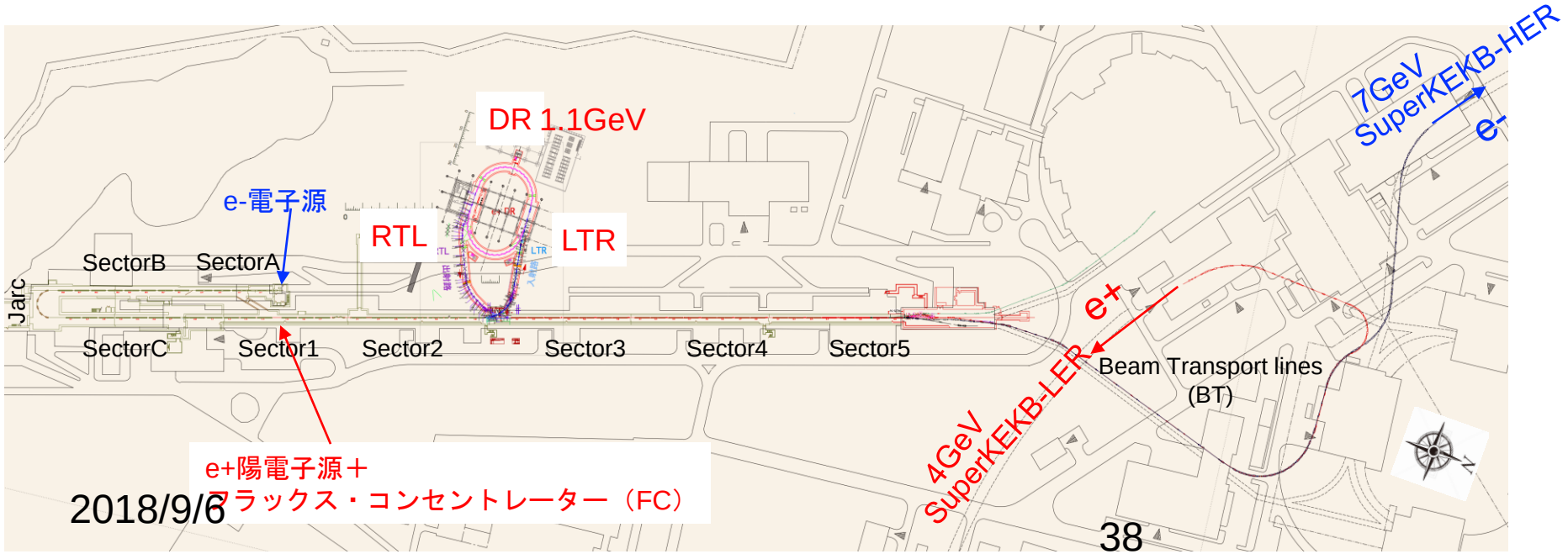
BT dump modeでの調整について

1. BT調整の必要性
   A) Emittance 増大問題
   B) 入射ビーム調整として
2. LINAC mode
   A) 電子、陽電子をPulse-to-pulseでDumpできない。
   B) Energy profileは、BTと同等。
   C) Straight dump？
3. IR作業
   1. どれくらいあるか？
4. BT安全システム変更
   1. 予算はどれくらい？
   2. 作業量は？

1. BT調整の必要性

A) Emittance増大問題

Request of injection beam from SuperKEKB			
	Phase 2	Phase3 Goal	
	2018	2019～202?	
		e+	e-
γεx [μm]	< 200	< 100	< 40
γεy [μm]	< 40	< 15	< 20
σδ [%]	0.16	0.16	0.07
Charge [nC]	1.5	4.0	4.0



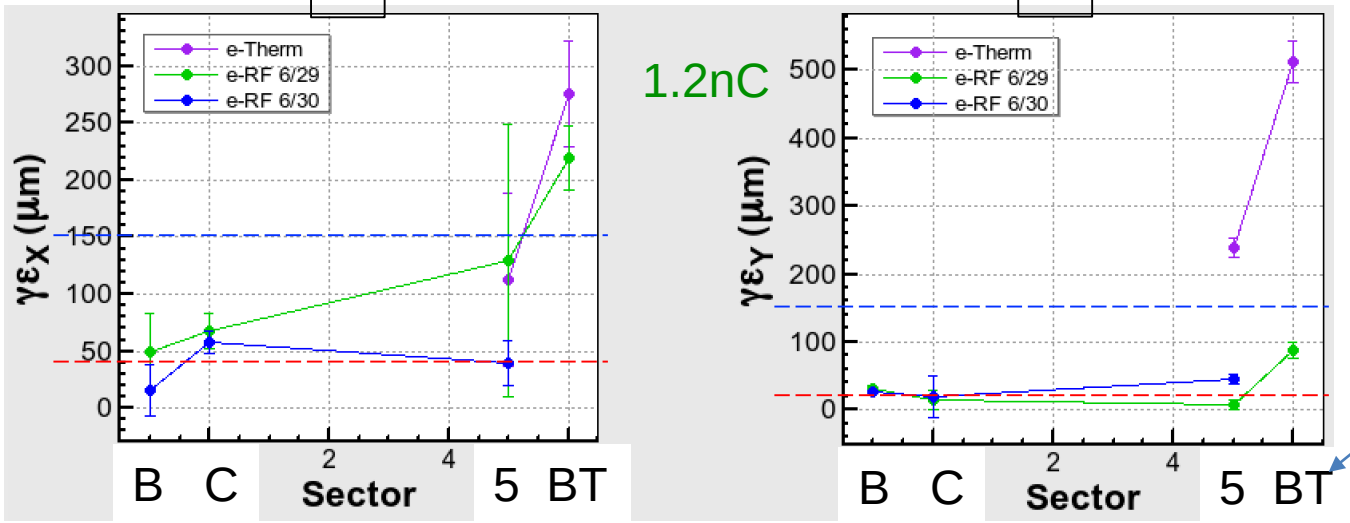
Emittance blowup in Phase 2

There is no question that the emittance blowup affects the BG.

Final Request from MR
Phase2 ----------
Phase3 final ----------

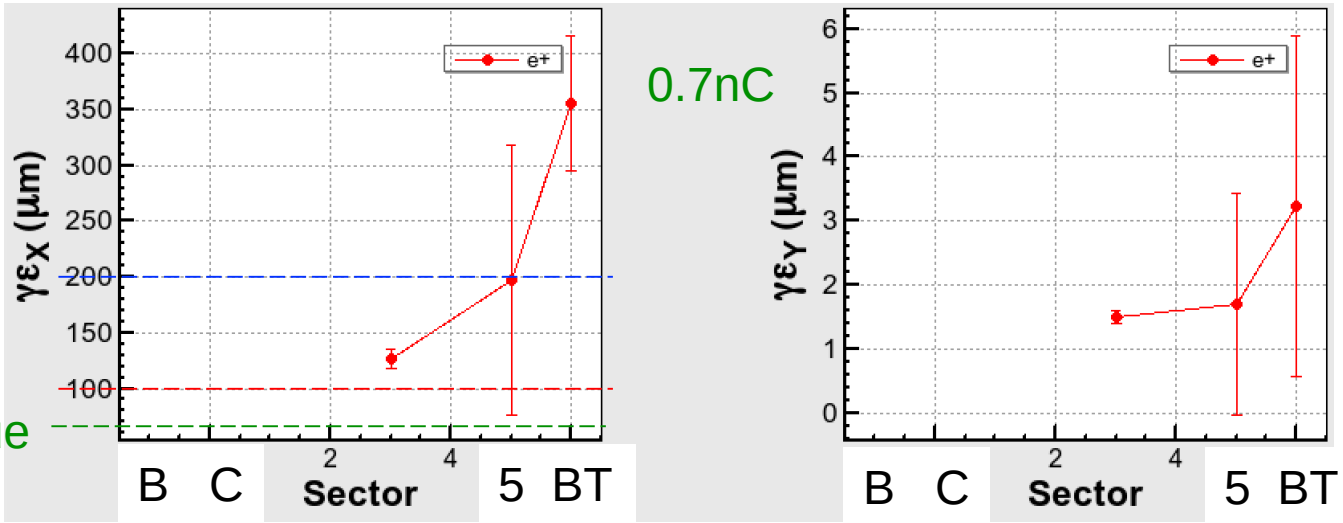
X Y

e-



Measurement at the upstream of BT

e+



40 ----
15 ----

DR designed value

More beam studies at BT will be needed.

LINAC Beam Studies (Oct.-Dec., 2018)

- RF Gun (M. Yoshida, X. Zhou, R. Zhang)
- Thermionic Gun
  - Tuning of Buncher (T. Natsui)
  - Q-Scan、10nC（T. Natsui and Y. Seimiya）
- 24 degree Line
  - Measurement and Correction of Dispersion（Y. Seimiya）
  - Measurement of Response and Aperture (Y. Seimiya)
  - Consistency Measurement of BPM (F. Miyahara)
- Jarc
  - Measurement and Correction of Dispersion（Y. Seimiya）
  - Bunch Compress（M. Yoshida)
  - OctoPos BPM (F. Miyahara)
- Measurement of Beam Position Jitter and Fluctuation (Y. Seimiya)
  - Binarization from Pulsed Magnet (T. Natsuim Y. Enomoto, M. Satoh, I. Satake)
  - Monitors of RF Phase and RF Induced wave
- Monitors of RF Phase and RF Induced wave (T. Miura, et al.)
- Primary side power fluctuation (T. Miura, T. Natsui)
- Investigation around Dummy Target (Y. Enomoto, H. Sugimura, T. Kamitani, Y. Ohnishi, Y. Funakoshi, N. Iida)
  - Beam Based Aligment (Ballistic Orbit、QuadBPM)
- Investigation of Solenoid magnet after Positron Target (T. Kamitani, Y. Ohnishi)
- Measurement of RF Energy Gain (T. Kamitani, Y. Ohnishi, T. Natsui, Y. Seimiya, M. Satoh)
- SY2 (N. Iida, H. Koiso)
  - Measurement of Dispersion
- Sector 3-5
  - Offset Injection (Y. Seimiya, N. Iida, T. Mimashi, T
  - Fudge Factor Measurement of Quad (Y. Seimiya,
  - QuadBPM (H. Sugimura), Mover Alignment (Y. E
- Coexistence with PF and PF-AR

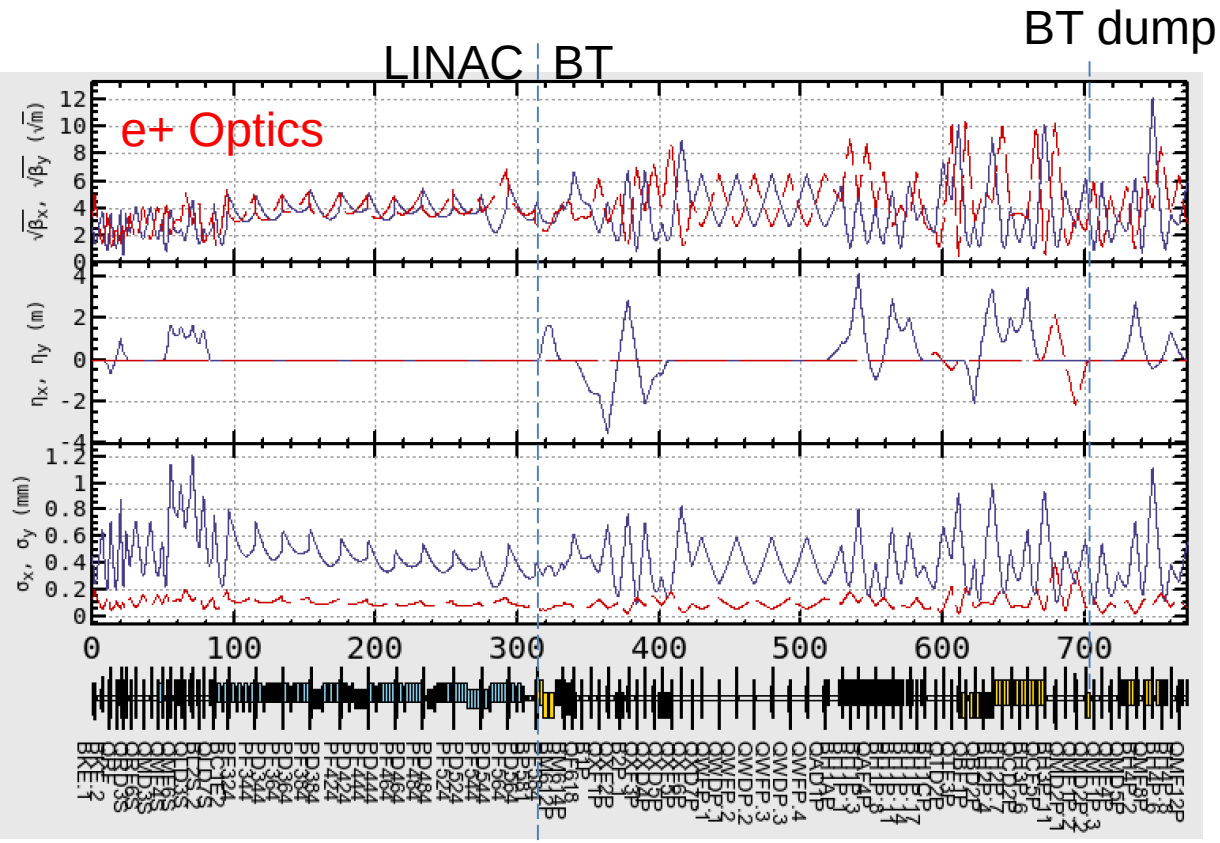
… Studies especially related to the BG: Core subjects

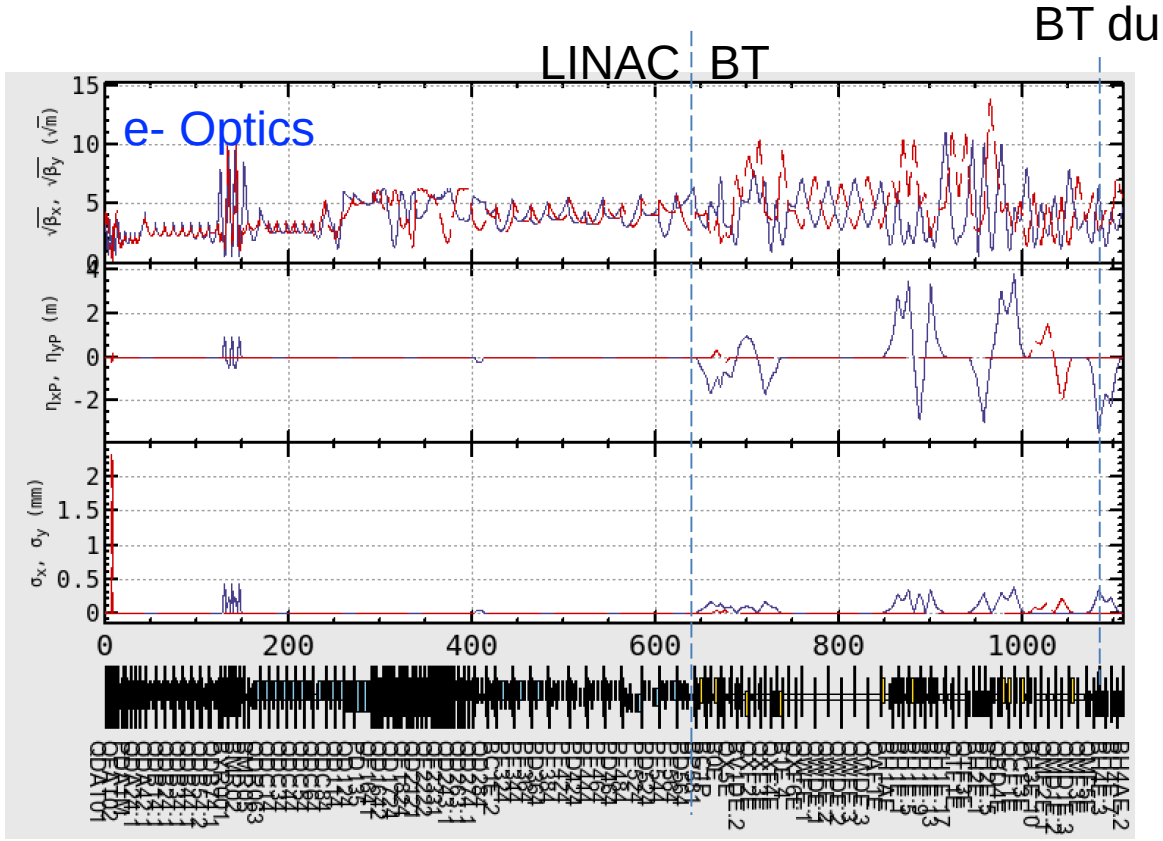
秋、冬のLINAC Studyでは、
Beam jitter, Energy jitter, OctoPos開発等、
様々な理解を進めることができた。

しかし、BT dump modeはMRがReadyでないとできないので、BTの調整時間を確保するには、MR運転中にもかかわらず入射を止めなければならない。
→少しでもBT調整の時間が取れないか？
→IR作業中にBTDump modeにできないか？

1. BT調整の必要性

B) 入射ビーム調整
LINACビームの診断ラインとしてのBT

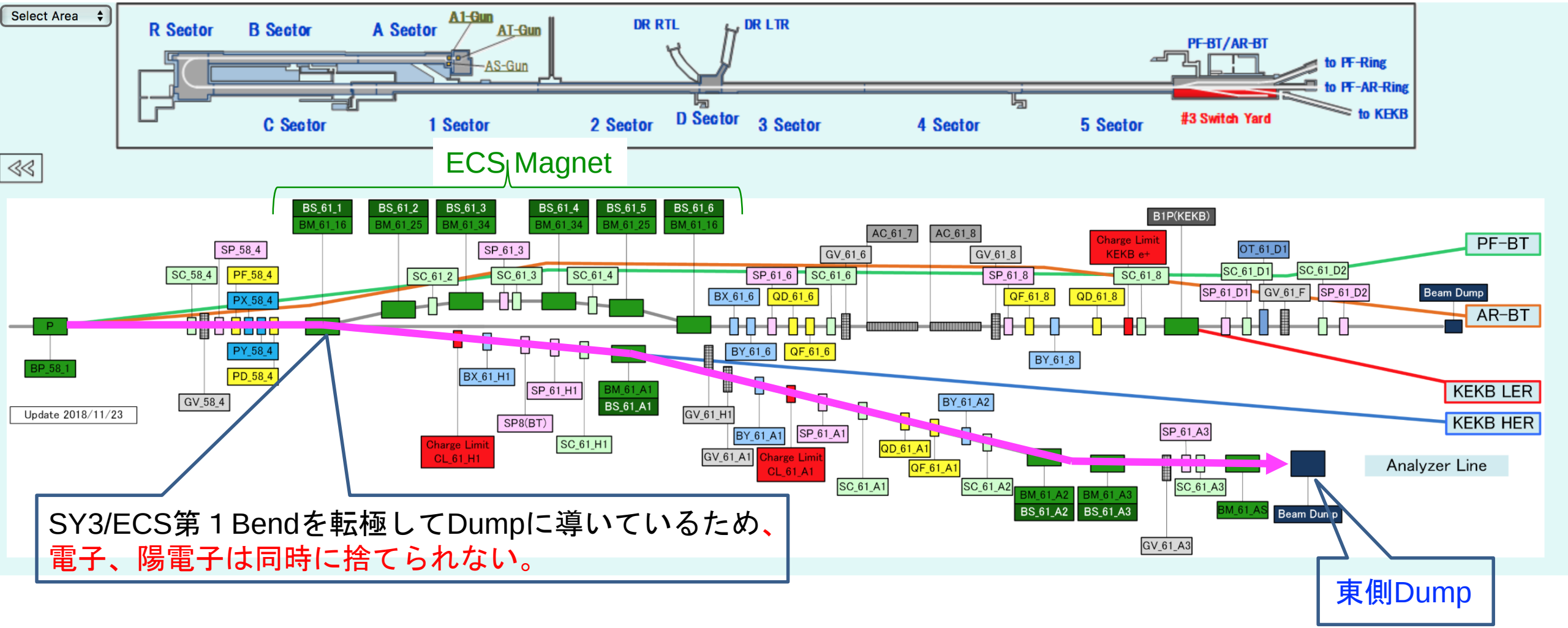




当然LINACとBTは繋がっていて、LINAC-BT全長の約４割を占める。
BT dumpまで調整しておけば、入射までは100m以下である。
LINACの診断ラインとしても重要。

2. LINAC mode

A) 電子、陽電子をPulse-to-pulseでDumpできない。



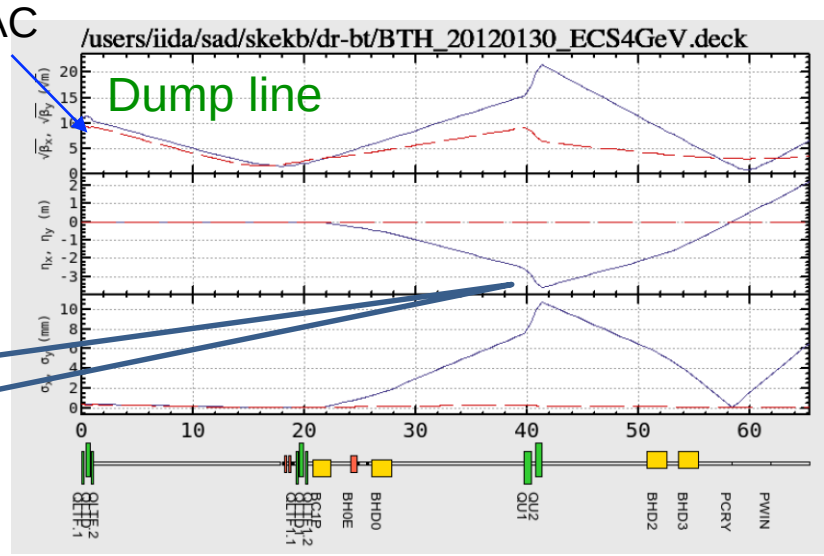
SY3/ECS第１Bendを転極してDumpに導いているため、
電子、陽電子は同時に捨てられない。

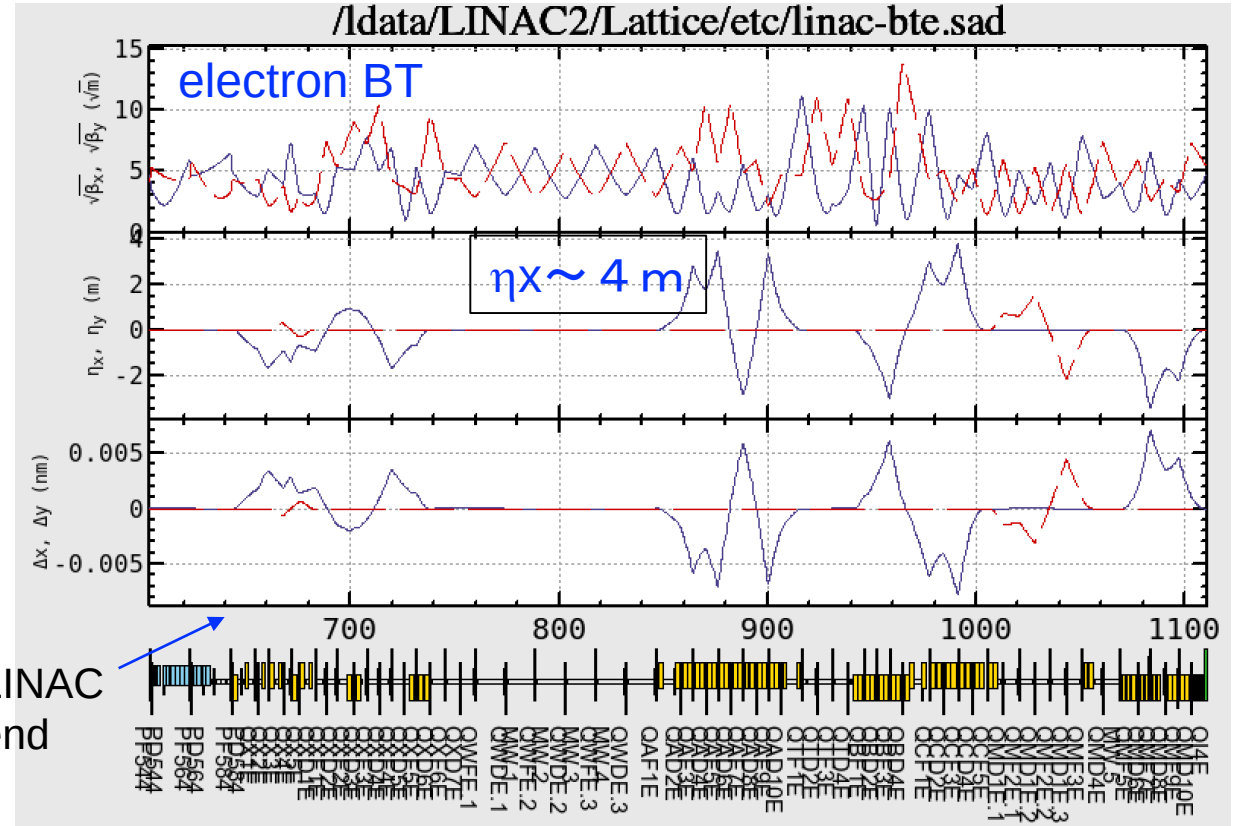
東側Dump

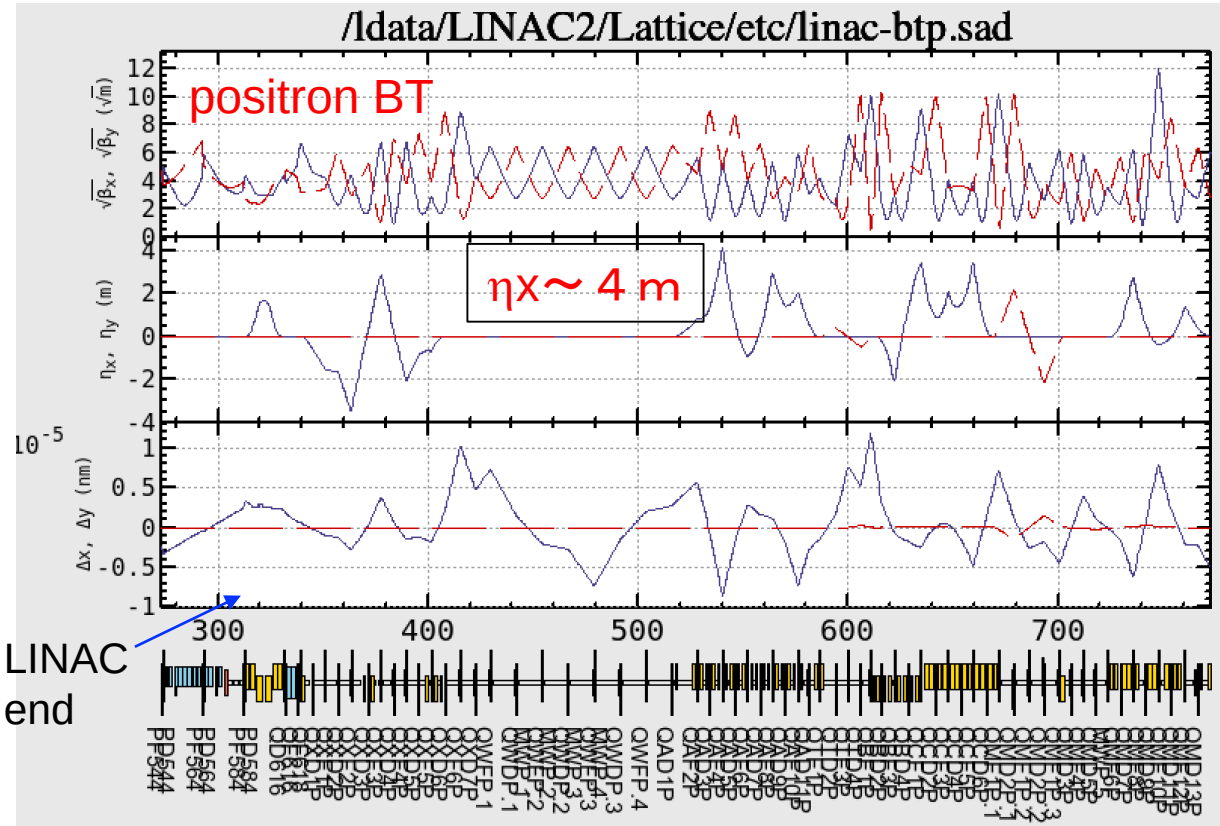
2. LINAC mode

B) Energy profileは、BTと同等

Dump line でも、
Dispersionは十分大きい（-3m）

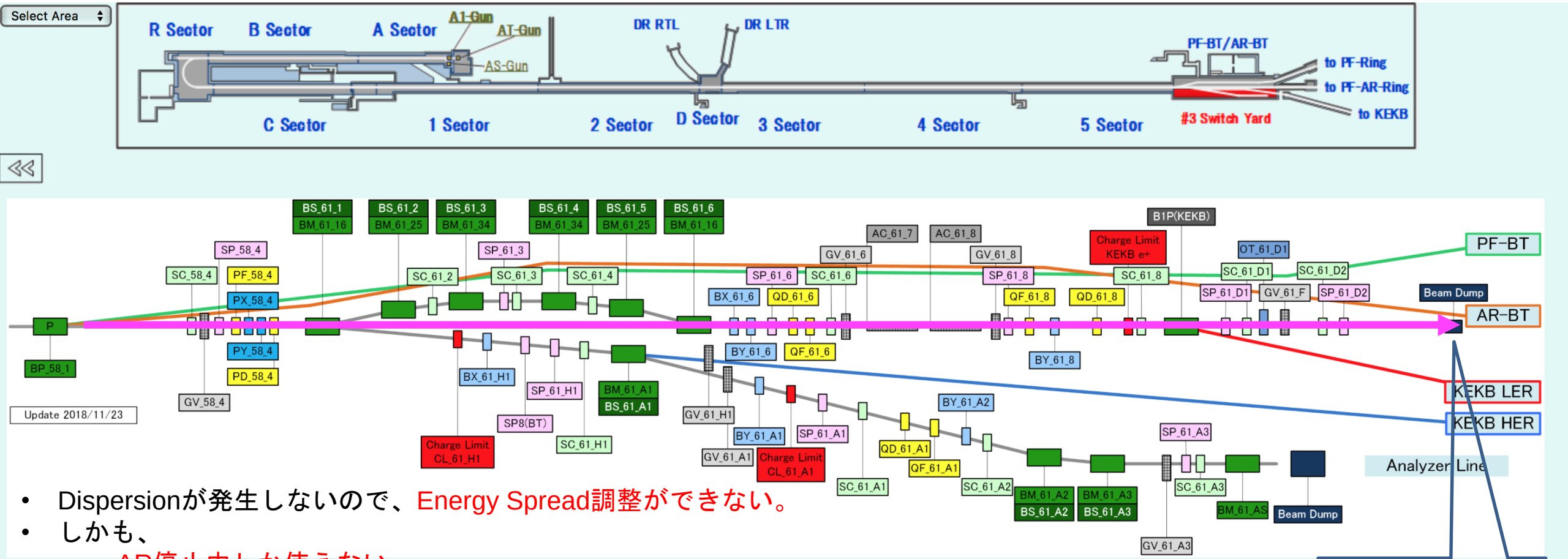






2. LINAC mode

C) Straight dump ?



- Dispersionが発生しないので、Energy Spread調整ができない。
- しかも、
  - AR停止中しか使えない
  - Dump前のBend内のChamberをクロス管に入れ替えないといけない
- 等の困難がある。

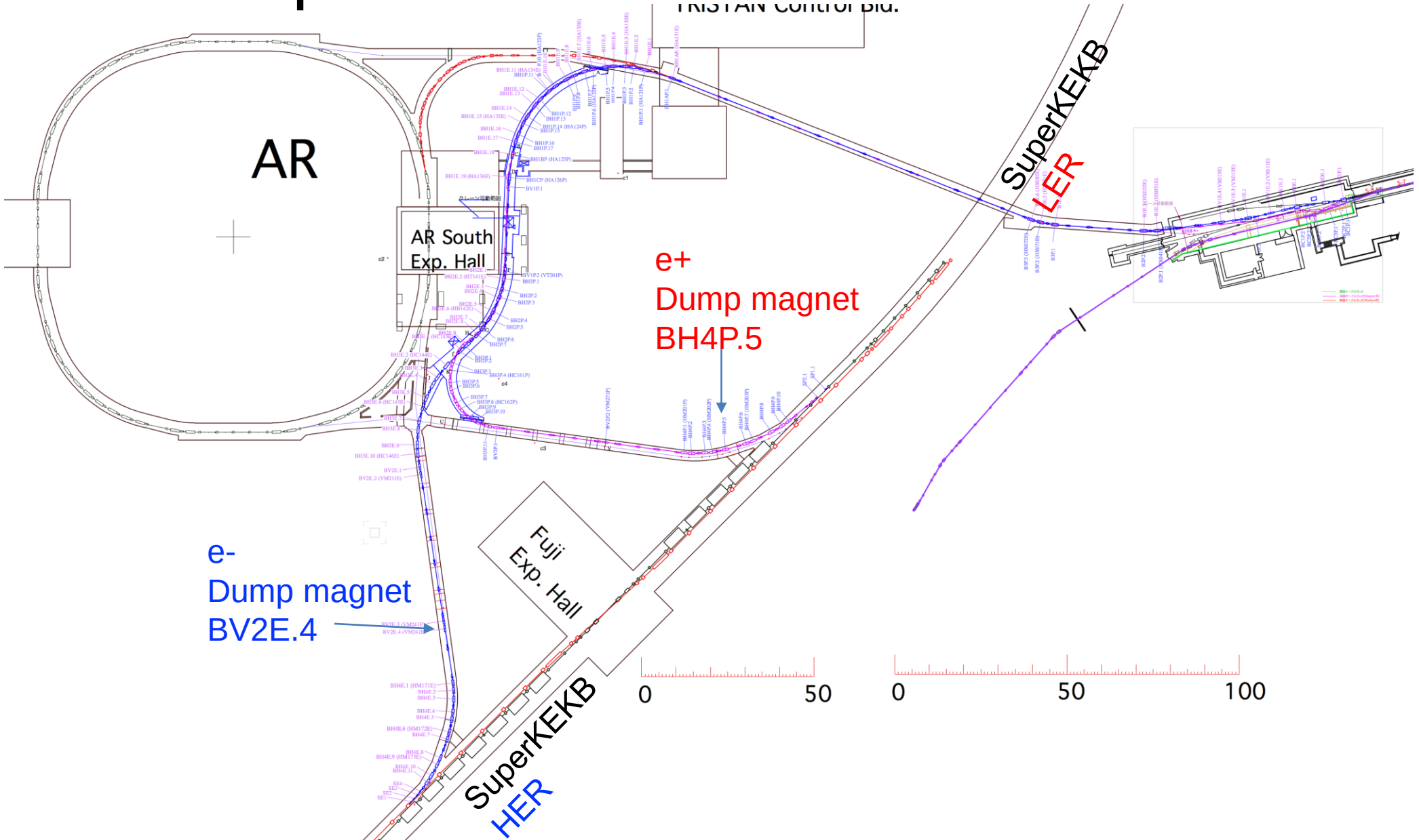
3. IR作業

- 今後どれくらいあるか？

  - 2020年（2021年？）夏、Belle2の作業で8ヶ月トンネル入域がある。
    - ８ヶ月間の最後の何日間かは、IR以外の作業がないことも考えられる。

  - IR関係の作業は、トラブル等により日常的に１～２時間程度の作業はあり得る。
    （不吉なのであまり考えたくありませんが）

4. BT dump mode



5-6月運転中の筑波入域

2019.6.19

N. Iida

木曜メンテ：5/16, 30, 6/13
メンテ日以外の筑波入域を調べた。

2019-05-07 12:06:39	筑波入域 (末次) コリメータ確認	27分
2019-05-08 10:14:34	筑波入域 (石橋、照井) 真空作業	112分
2019-05-08 10:31:45	筑波入域 (白井) 真空作業	
2019-05-08 10:57:23	筑波入域 (大山、坂木、TNS:吉原) 放射線測定	
2019-05-09 16:43:00	筑波入域(田中(秀)、Dmytro、Bjoern、Hua) PXD メンテナンス	34分
2019-05-13 15:39:44	筑波入域(ドミトリ、ジュゼッペ) KLMの点検	37分

2019-05-07 12:33:30	筑波退域 (末次)
2019-05-08 11:06:35	筑波退域 (大山、坂木、TNS:吉原)
2019-05-08 12:06:29	筑波退域 (石橋、照井、白井)
2019-05-09 17:17:43	筑波退域(田中(秀)、Dmytro、Bjoern、Hua)
2019-05-13 16:16:41	筑波退域(ドミトリ、ジュゼッペ)

2019-06-05 10:32:58	筑波入域（田中(秀)、Levit、Mueller） PXDメンテナンス	29分
2019-06-06 08:01:50	筑波入域（飛山） ロガー交換作業	4分
2019-06-08 09:43:31	筑波入域（中村(克)、Antonio、坪山） 電源の交換	28分

2019-06-05 11:01:04	筑波退域（田中(秀)、Levit、Mueller）
2019-06-06 08:05:00	筑波退域（飛山）
2019-06-08 10:15:18	筑波退域（中村(克)、Antonio、坪山）

2019-05-21 01:51:57	筑波入域 (大木、大澤) 電磁石点検	60分
2019-05-21 01:57:35	筑波入域 (中村衆) 電磁石点検	
2019-05-25 17:15:49	筑波入域（飛山氏、MSC 田中直、MSC 白石） 冷却水調整	7分
2019-05-28 09:07:48	筑波入域 (大澤) 冷却水確認	20分
2019-05-28 13:47:07	筑波入域(足立、パベル) 検出器チェック	137分
2019-05-28 14:50:23	筑波入域(ドミトリ、スワガト、クリス) KLMの点検	
2019-05-28 14:52:23	筑波入域(白井、照井) 真空作業	

2019-05-21 02:51:47	筑波退域 (大木、大澤、中村衆)
2019-05-25 17:28:05	筑波退域（飛山氏、MSC 田中直、MSC 白石）
2019-05-28 09:27:37	筑波退域 (大澤)
2019-05-28 15:09:18	筑波退域(白井、照井)
2019-05-28 15:51:34	筑波退域(足立、パベル)
2019-05-28 16:04:09	筑波退域(ドミトリ、スワガト、クリス)

5/7-6/8：
434+61=495分

QCS Quench時

2019-06-09 23:10:00	筑波入域 (末次) 真空調査	5分
2019-06-09 23:25:15	筑波入域 (大内、ZONG Zhanguo) QCS確認	18分
2019-06-10 00:37:35	筑波入域 (日立プラント:遠藤、日立テクノロジー:伊佐) QCSR冷凍機真空ポンプ復旧	7分
2019-06-10 02:19:30	筑波入域 (日立プラント:遠藤、日立テクノロジー:伊佐) 真空ポンプ立上げ	29分
2019-06-10 07:20:05	筑波入域 (大内、日立プラント:遠藤) 真空ポンプ立上げ	5分
2019-06-10 10:06:22	筑波入域(照井、白井、末次) 真空作業	93分
2019-06-10 11:14:03	筑波入域(ユーサ:村瀬) 真空作業	
2019-06-10 11:16:59	筑波入域(大内、日立プラント:遠藤) 真空ポンプ作業	
2019-06-10 13:30:58	筑波入域(田中(秀)、Qingyuan、Boqun) PXDメンテナンス	30分
2019-06-10 14:10:51	筑波入域(照井、白井) 真空作業	43分
2019-06-11 14:18:33	大内氏より、筑波入域の連絡あり →飯田氏へ連絡、了承	34分
2019-06-11 14:20:25	筑波入域の為、安全Magnet立ち下げ	
2019-06-11 14:39:26	筑波入域（大内、宗、日立：遠藤） QCS 点検	13分
2019-06-11 15:14:57	大内氏より、筑波入域の連絡あり →飯田氏へ連絡、了承	
2019-06-11 15:30:54	筑波入域（大内） QCS 点検	43分
2019-06-11 15:36:54	筑波入域（日立：遠藤） QCS 点検	
2019-06-11 15:51:32	筑波入域（宗） QCS 点検	

2019-06-09 23:15:06	筑波退域 (末次)
2019-06-09 23:43:02	筑波退域 (大内、ZONG Zhanguo)
2019-06-10 00:44:58	筑波退域 (日立プラント:遠藤、日立テクノロジー:伊佐)
2019-06-10 02:48:00	筑波退域 (日立プラント:遠藤、日立テクノロジー:伊佐)
2019-06-10 07:24:53	筑波退域 (大内、日立プラント:遠藤)
2019-06-10 11:21:44	筑波退域(大内、日立プラント:遠藤)
2019-06-10 11:39:53	筑波退域(照井、白井、末次、ユーサ:村瀬)
2019-06-10 14:00:52	筑波退域(田中(秀)、Qingyuan、Boqun)
2019-06-10 14:53:29	筑波退域(照井、白井)
2019-06-11 14:52:20	筑波退域（大内、宗、日立：遠藤）
2019-06-11 16:13:48	筑波退域（大内、宗、日立：遠藤）

2019-06-19 09:03:20	筑波入域(田中(秀)、Qingyuan、Felix) PXDメンテナンス	24分
2019-06-19 09:23:44	筑波入域(西田) PCの保守	6分
2019-06-19 09:30:03	筑波入域(照井) 真空作業	14分

2019-06-19 09:27:20	筑波退域(田中(秀)、Qingyuan、Felix)
2019-06-19 09:29:16	筑波退域(西田)
2019-06-19 09:44:02	筑波退域(照井)

5/7-6/8：
434+61=495分

6/9-6/19：
320+44=364分

5/7-6/19：
495+364=859分=14時間32分