Update from J-PARC Slow Extraction

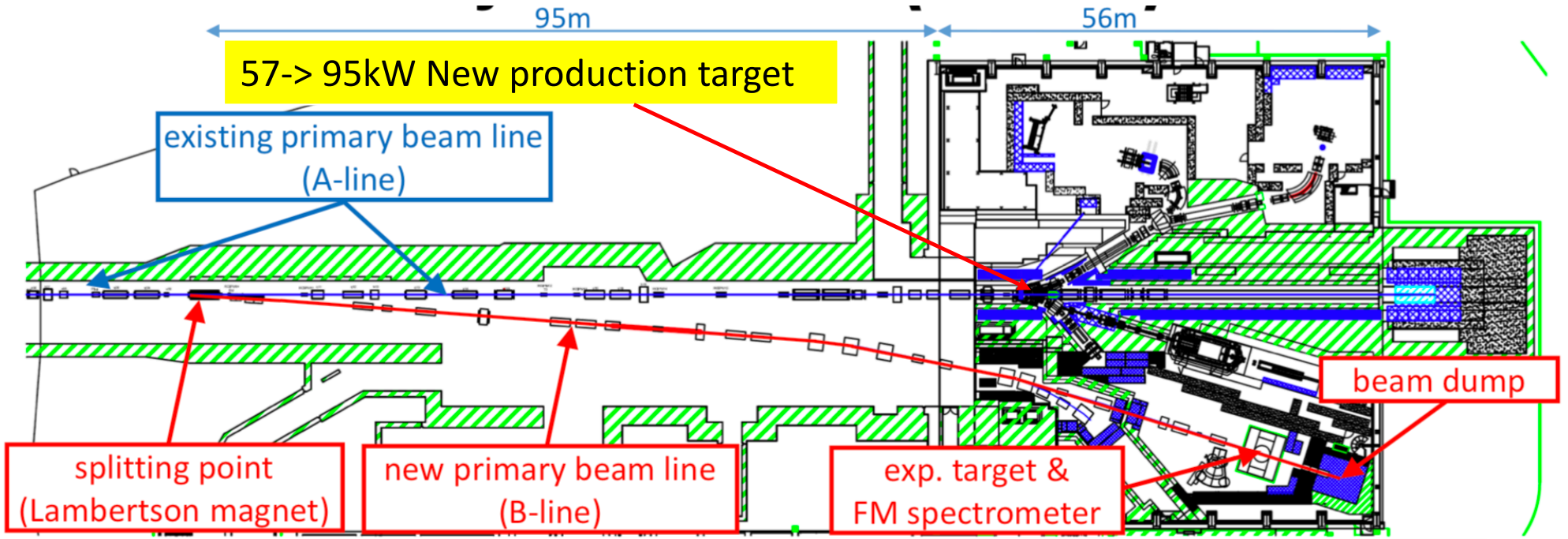
2020.11.16　US-JAPAN CM (remote by ZOOM)

M. Tomizawa

- Last SX RUN Report
- Next SX RUN Plans

New Target (A-line) and new beam line (B-line)

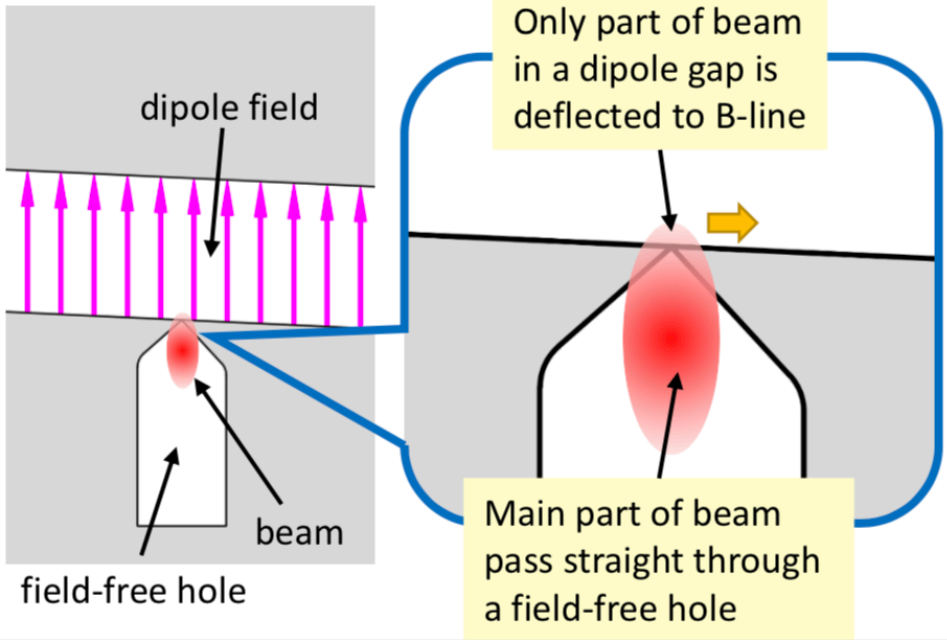
J-PARC PAC, H. Takahashi



- Part of primary proton beam is split from existing primary beam line (A-line) and is directly used for user experiments.
- Max intensity: 2.6 x 10^{10} protons/spill (24W equivalent)
- Beam splitting is made with Lambertson magnet.

Beam intensity in B-line is very sensitive to main beam hallo!

Cross section of Lambertson magnet poles



Last SX Operation Summary (RUN84, 85)

2020.4.13-4.14 Abort Dump mode Tuning
2020.5.19 Abort Dump mode Tuning
2020.5.23 SX Start
2020.5.29 50kW SX user operation start

2020.6.25 50kW SX operation finished

・The scheduled 50kW SX operation has completed (efficiency 99.45%, Spill duty 50-55%).
・The SX beam has been successfully delivered to A and B beam lines at the same time.

ESS2 had a dark current 10-15 μA and small vacuum pressure spikes
at nominal 104.4kV before RUN84.
-> RUN84,85
ESS1 (Ti ESS) 70kV -> 104.4 kV
ESS2 (SUS ESS) 104.4kV->75kV

At the beginning of the RUN, frequent sparks in ESS1 were seen,
however they gradually decreased in frequency with the beam operation increasing
the beam intensity several steps.

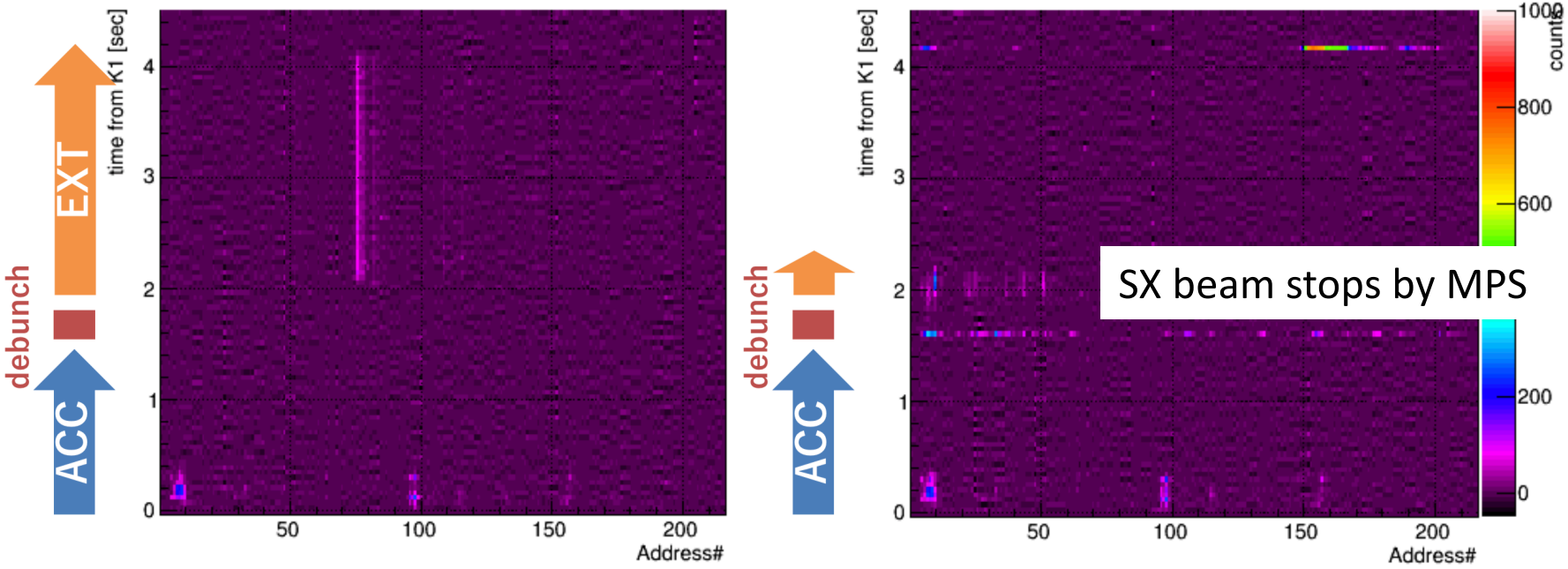
Instability during debunch process for SX

Normal shot

2020 May 28 18:59:33 - Run 85 Shot 12063

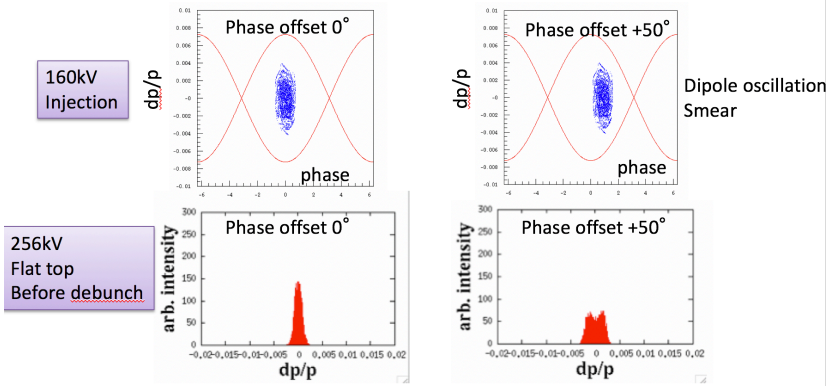
With instability at debunch timing

2020 Jun 02 01:34:06 - Run 85 Shot 48670



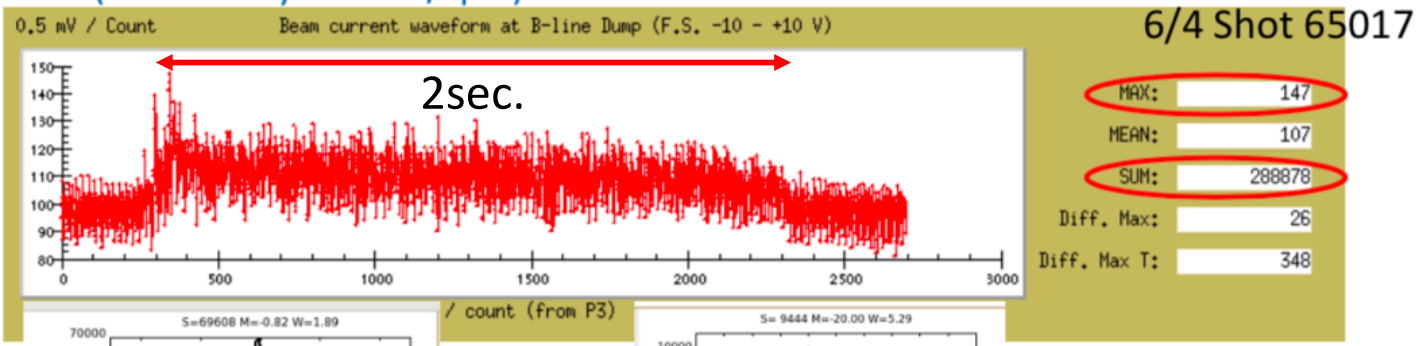
Mitgation:
RF Phase offset Injection
to the RF buckets

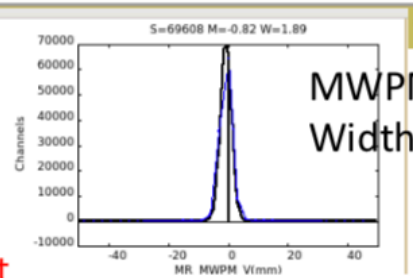
V or/and H Coherent Oscillation
Electron cloud observed



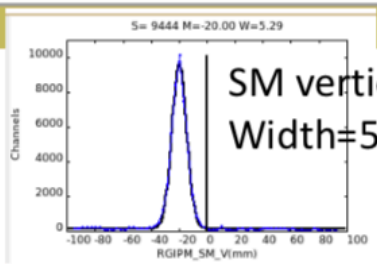
MPS due to a large amount of beam extraction to B-line

normal shot (B-intensity: $1x10^8$ /spill)



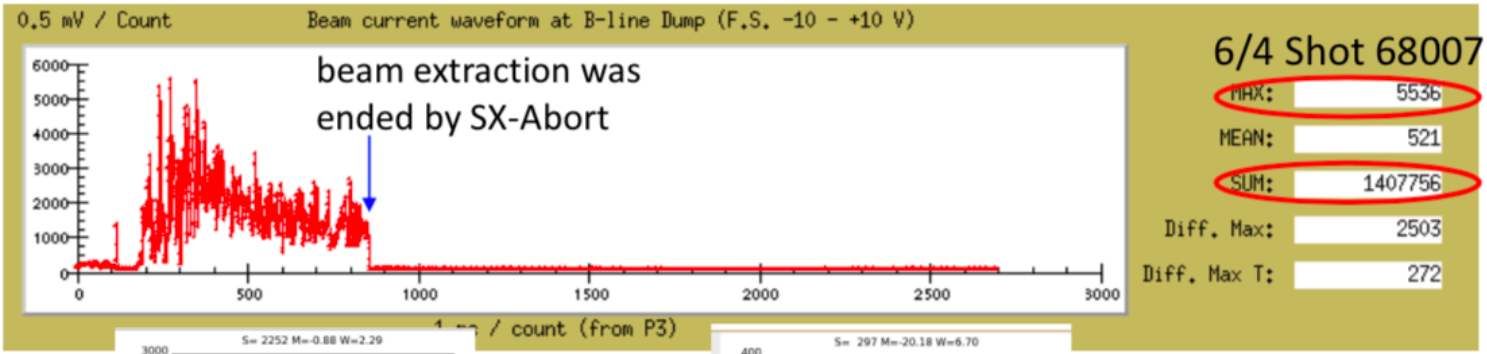


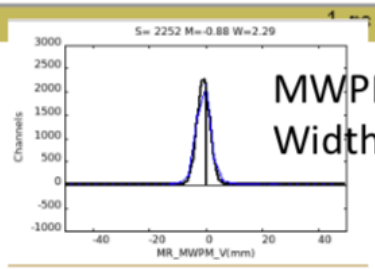
MWPM vertical
Width=1.89mm



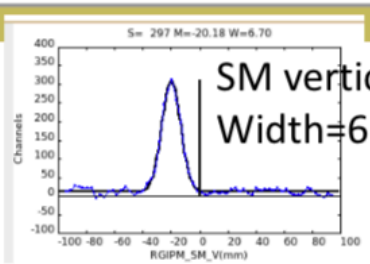
SM vertical
Width=5.29mm

MPS shot





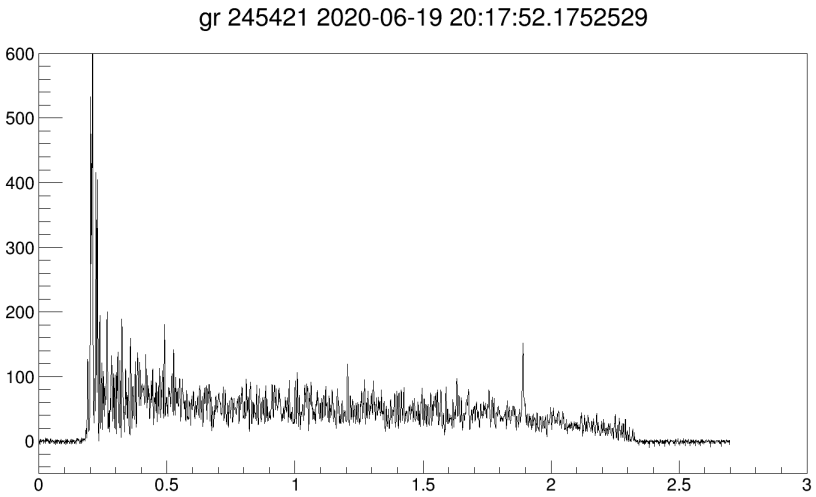
MWPM vertical
Width=2.29mm

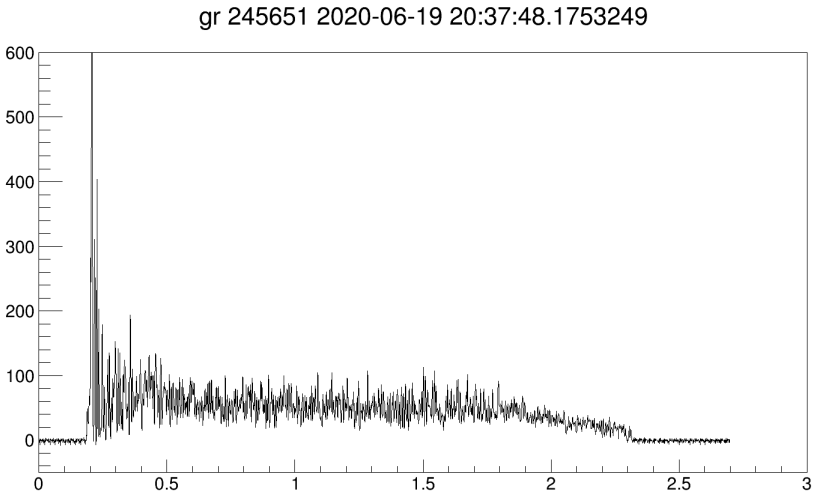


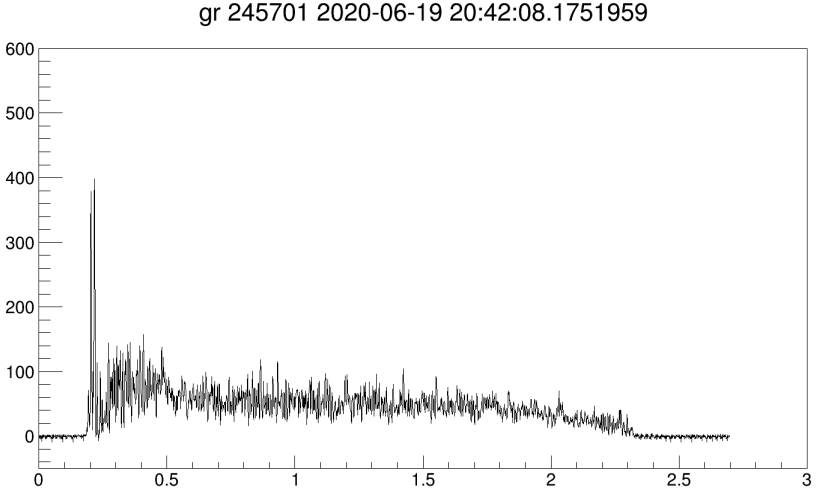
SM vertical
Width=6.70mm

※These figures are in a "typical" case.
No clear broadening was observed in some MPS shots.

The beam intensity in B-Line is very sensitive to the Instability
Those events have any problem in A-Line only operation mode
Mitigated by RF phase offset injection 60deg -> 65deg





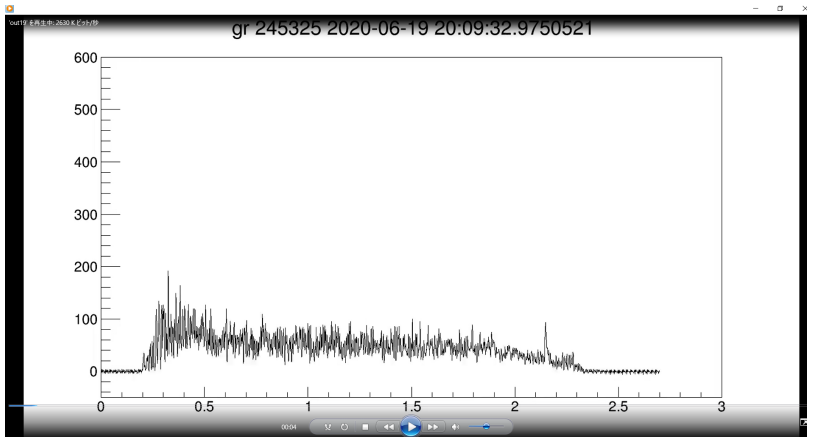


B-Line Spill Spikes

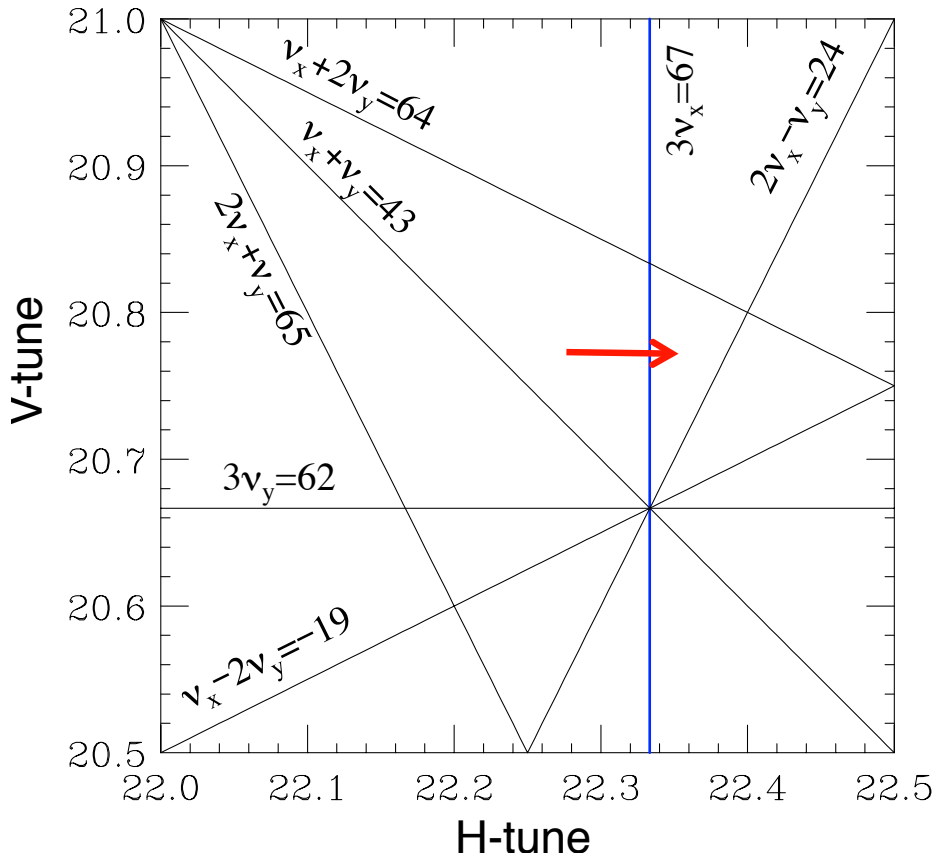
at the beginning of spills
did not induce B-line MPS,
But have a potential to give
a damage to detectors

Actual shot number: 245420, 245650, 245700

Good case



B-Line Spill Spikes



◎ Mechanism　Qx+Qy=43 effect

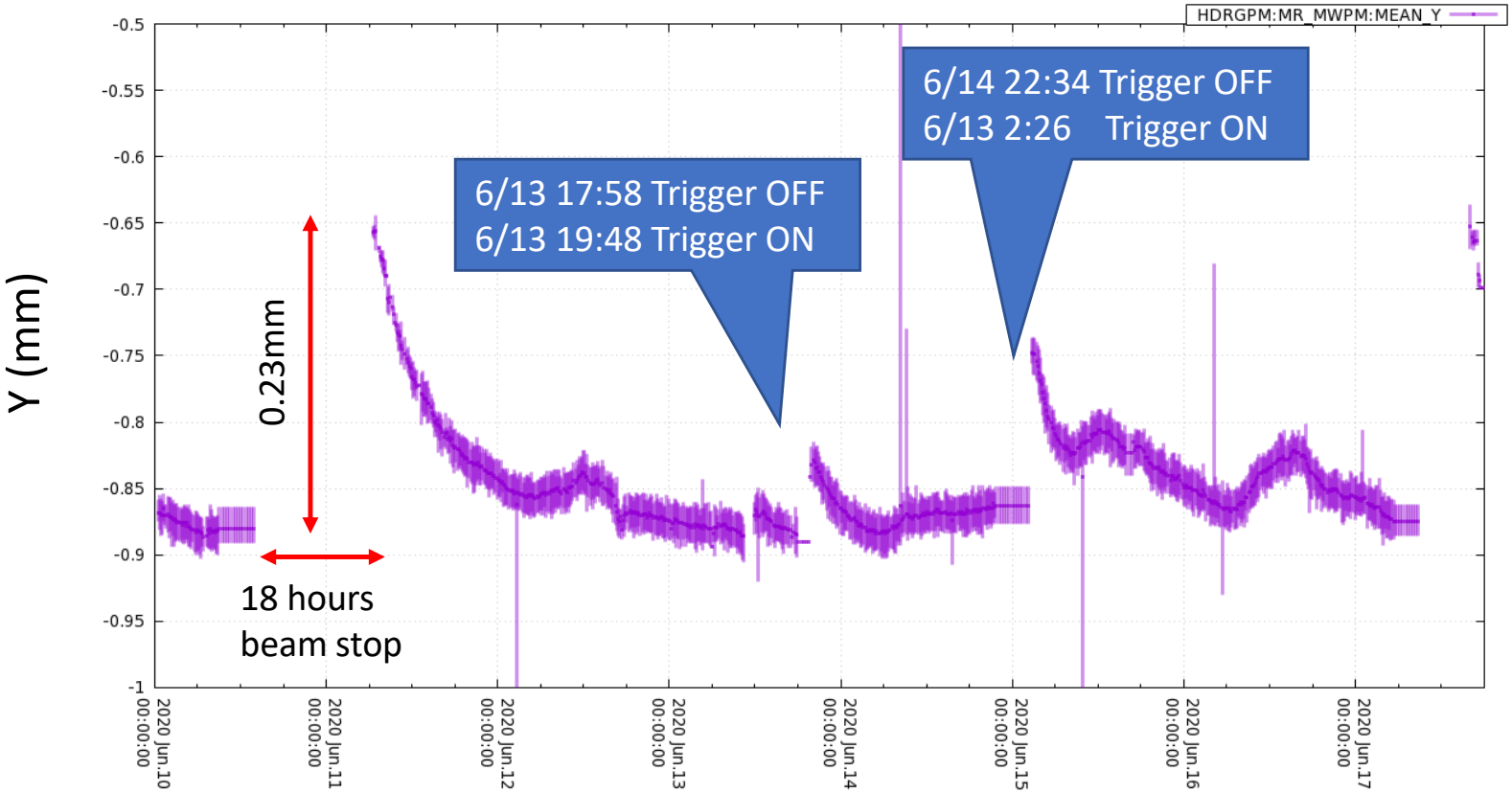
The beam with a large H-amplitude can have a large V-amplitude.

◎ Mitigations

・Qy,（Qx） optimized avoiding the resonance in whole acceleration pattern

・Further resonance correction by four Skew Q magnets

Vertical main beam position drift at MWPM (MR exit to HD beam line)



The Y drift could affect A-line targeting and B-line beam intensity.

```
 run=  85 shot=  139180
Print["  time= ",wholetime];
 time= 2020-06-10_08.59.20.791
.................................

 run=  85 shot=  139260
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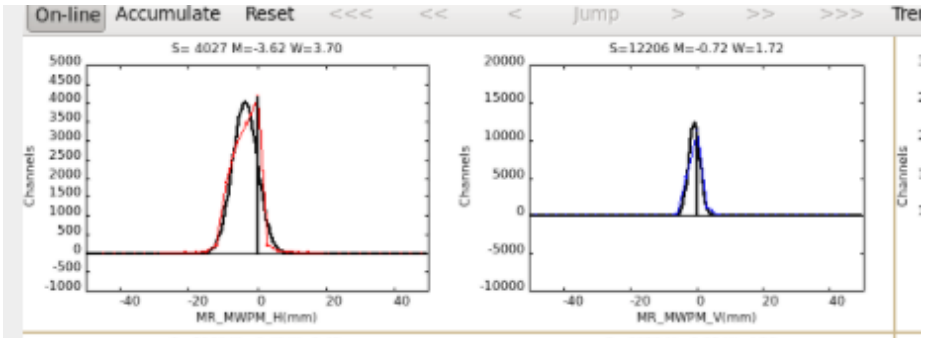
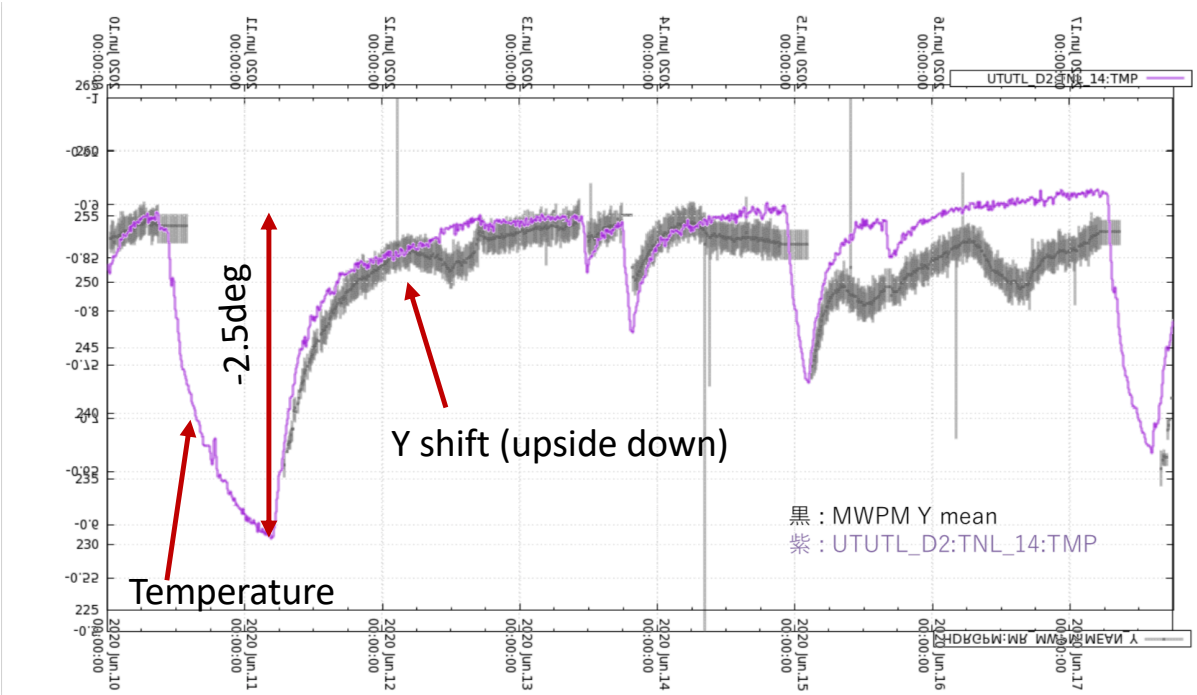
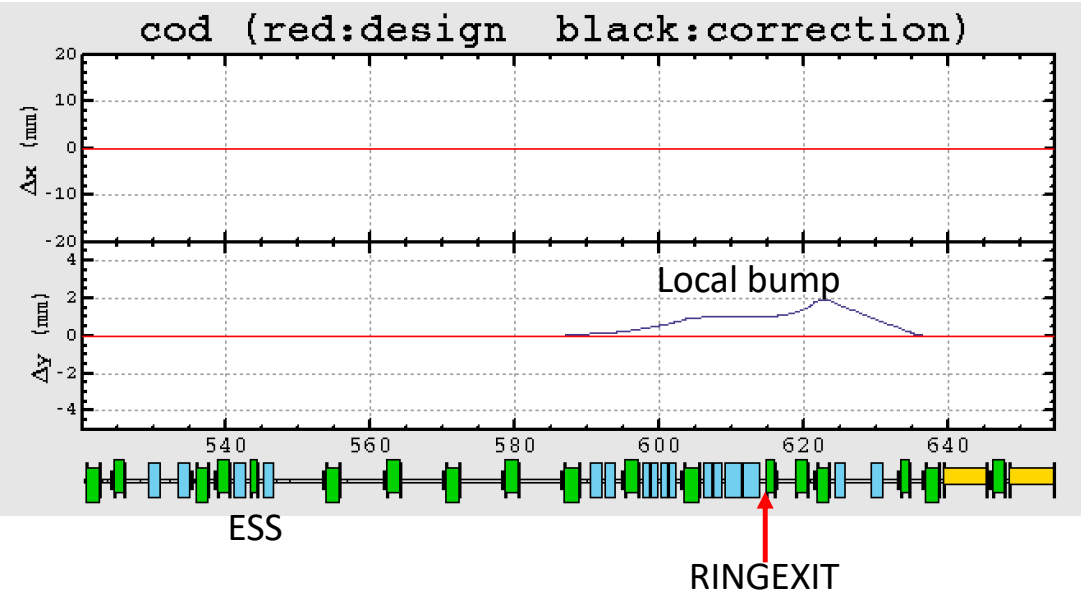




The Y drift correlates with MR tunnel temperature.

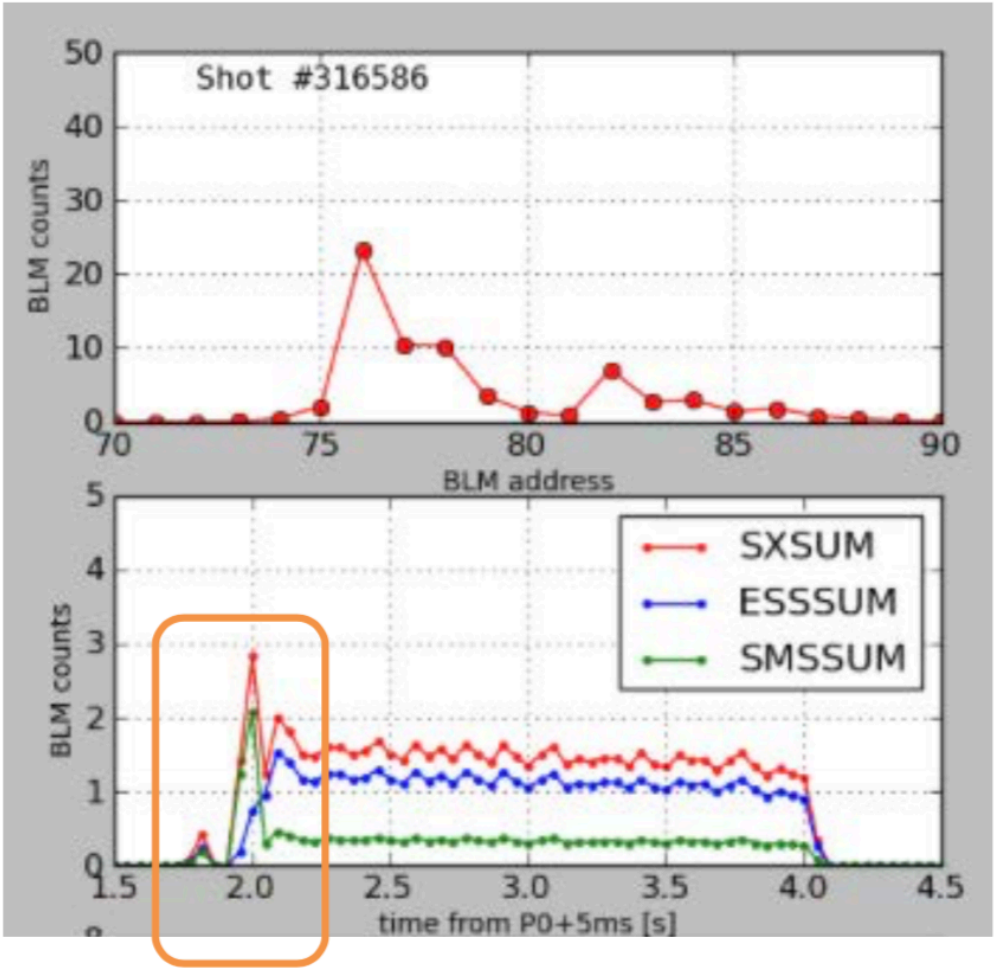
The reason is unknown.

The drift could be corrected by exciting 4-vertical steering magnets around MR exit (DY=+1mm DPY=0mrad @RINGEXIT extreme case)



Before Search dK0[rad]	
ZSV31_72	0.000000
ZSV32_74	0.000000
ZSV33_77	0.000000
ZSV34_79	0.000000
ZSV35_81	-.000035
ZSV36_83	-.000065
ZSV37_86	0.000077
ZSV38_88	-.000115
ZSV39_90	0.000000

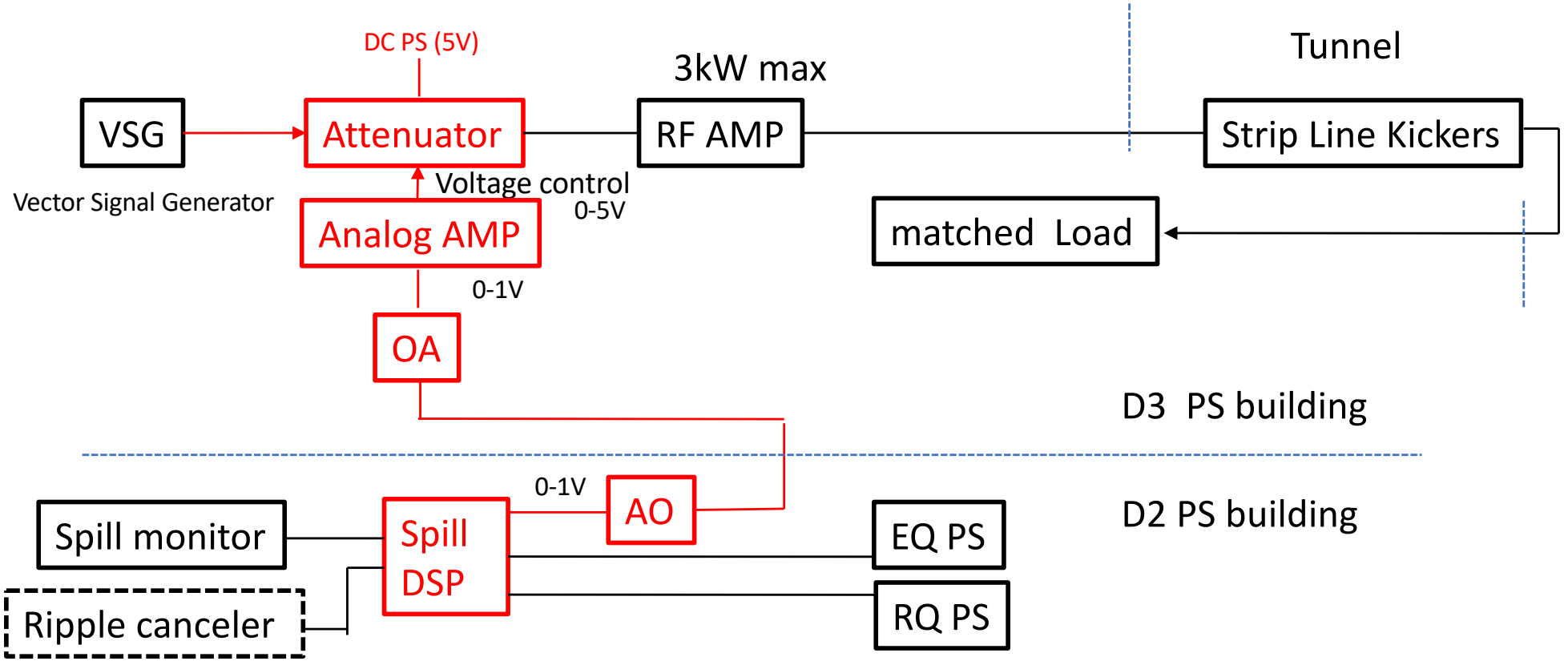
60 kW SX Demonstration



extraction eff. 99.38%
spill duty 61.5%
spill length 1.92s
（global offset 70deg ）

Beam loss before and at the begin of the extraction will be reduced by tuning of horizontal betatron tune and chromaticity.

Time Response Measurement for Future TRF feedback

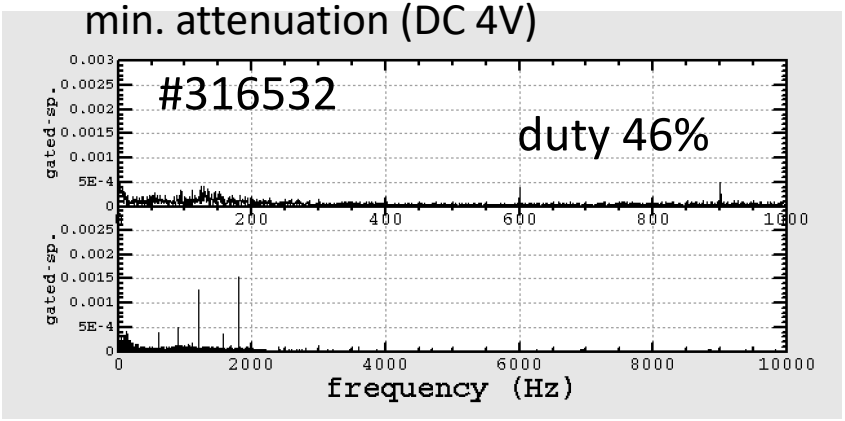


Spill monitor signal: for spill feedback
Ripple canceler signal : for spill feed-forward
Vector Signal Generator: for spill feed-forward
Attenuator: for spill feedback
TRF can be applied for both feedback and feed-forward

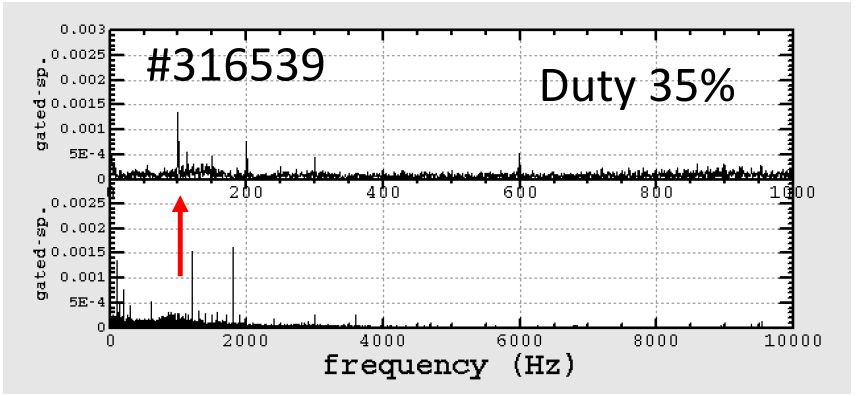
Beam Spill FFTs

TRF Response Setup System check for sinusoidal attenuation

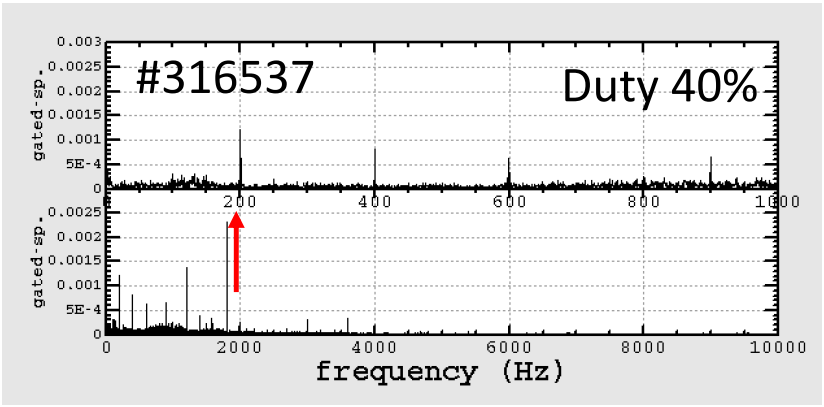
min. attenuation (DC 4V)



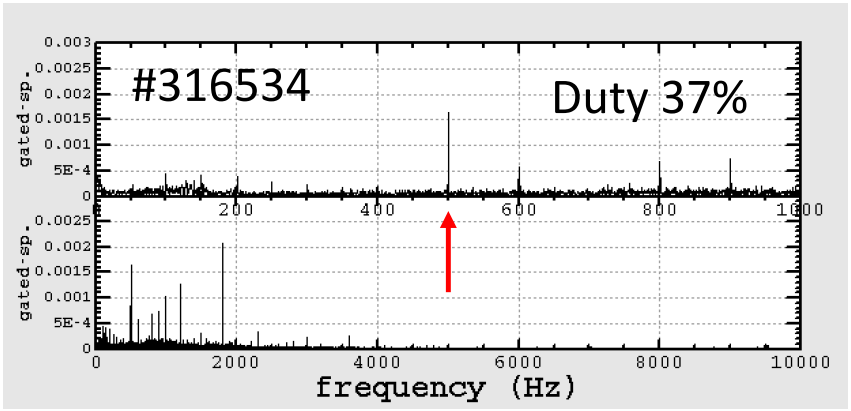
100 Hz



200 Hz

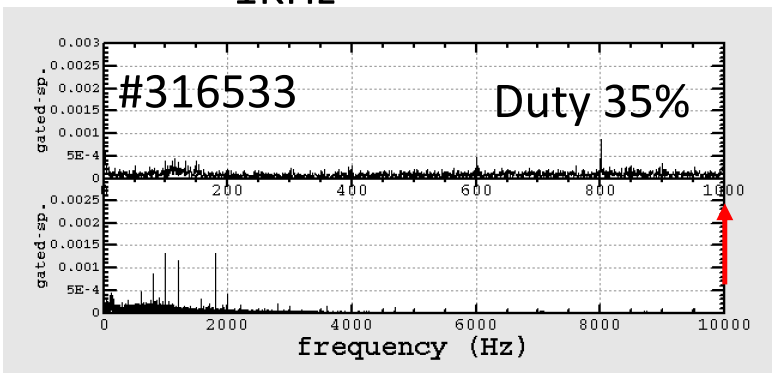


500 Hz



500Hz peak seen

1KHz

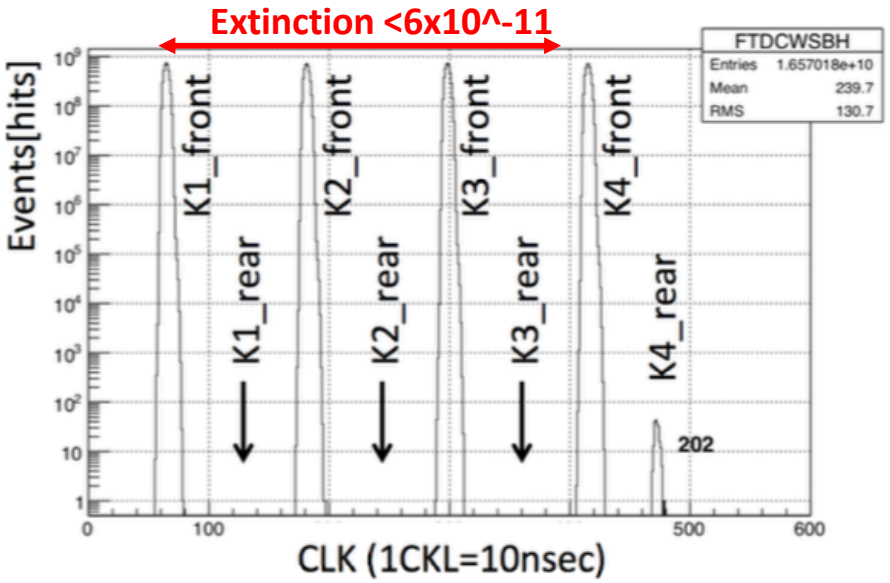


1KHz peak ?

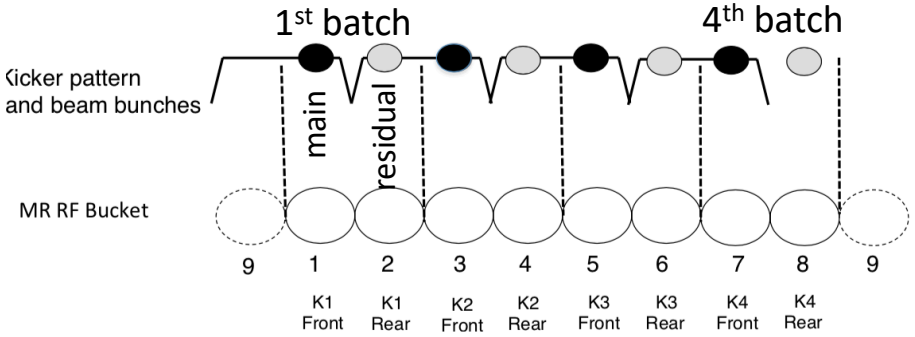
TRF FB time response > 500Hz

Extinction

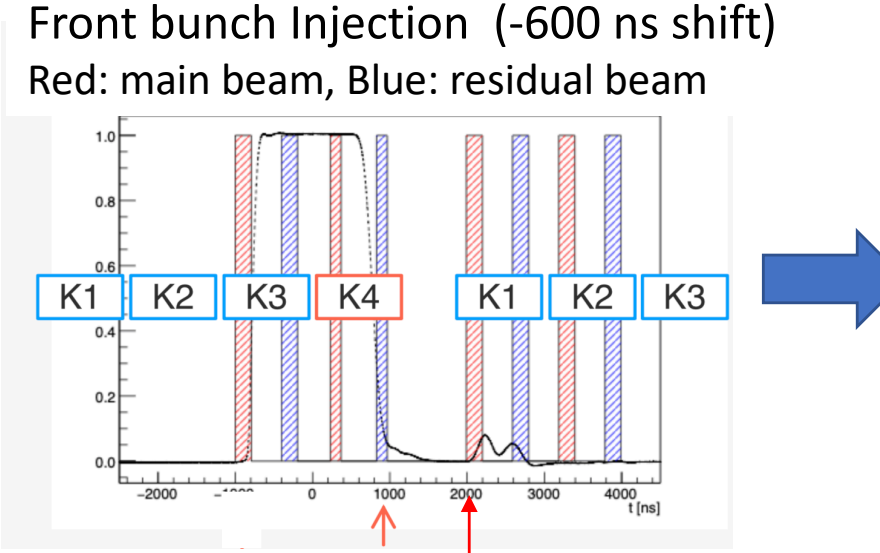
Measured 8 GeV Slow-extracted beam time structure



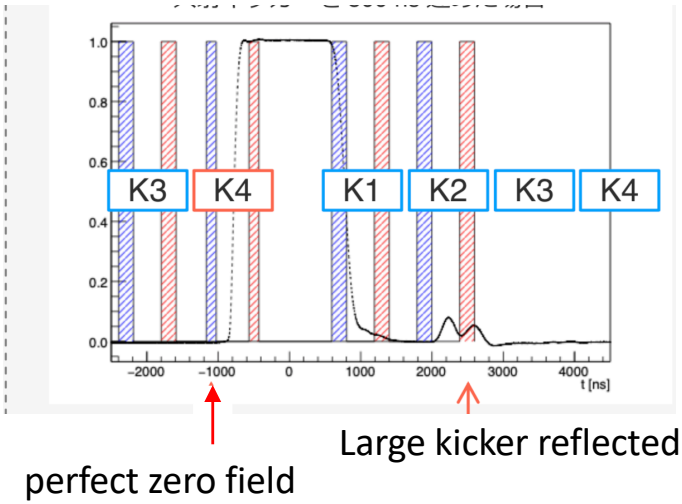
Empty buckets by a chopper (residual rate 10^{-6} level)
The residual beam is killed by a MR kicker timing shift
(Front bunch Injection)



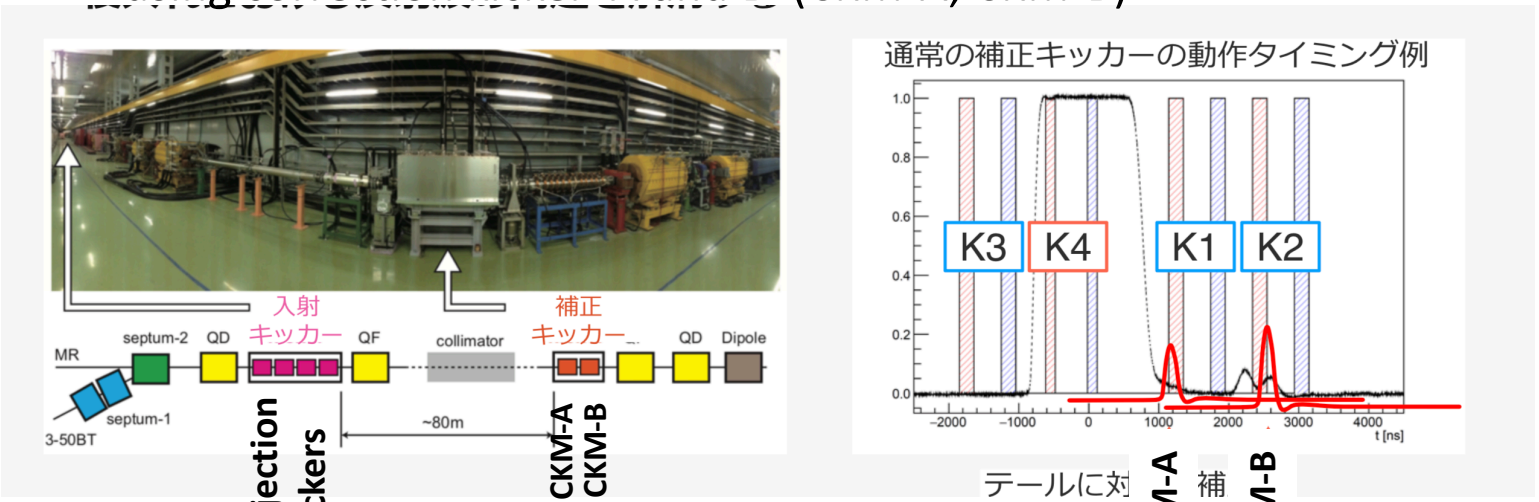
Front bunch Injection (-600 ns shift)
Red: main beam, Blue: residual beam



Rear bunch Injection (800 ns shift)
Red: main beam, Blue: residual beam

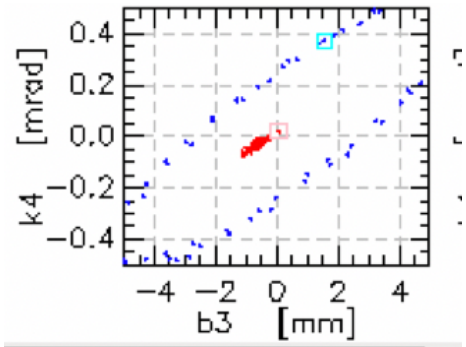


Demonstration of Injection error correction for normal Injection Scheme using correction kicker A and B (CKM-A, CKM-B)



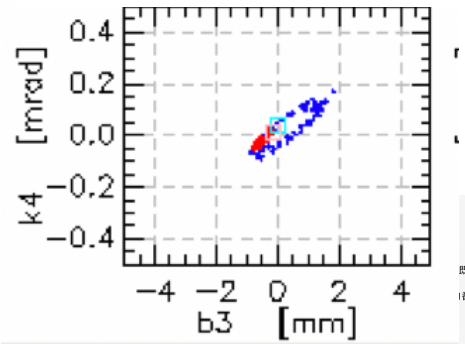
turn by turn plot

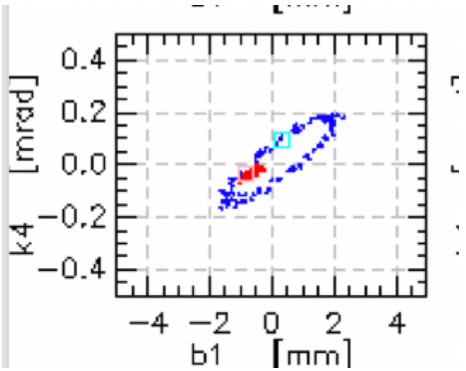
w/o correction kicker



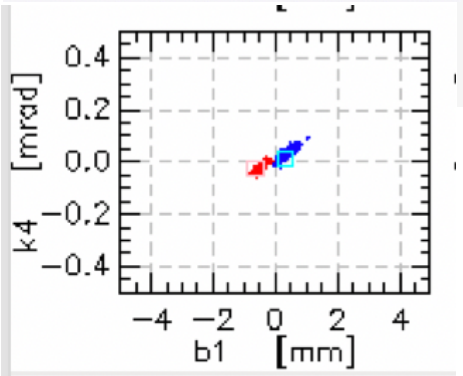
C-KM B

w/ correction kicker

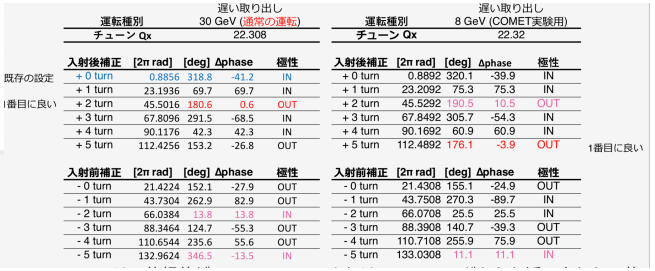




C-KM A



30GeV SX:
CKMs fired at 2 turn
before injection kicker timing
(phase advance 13.8deg
@Qx=22.308)



遅い取り出し 30 GeV (通常の運転)					
運転種別					
チューン Qx			22.308		
入射後補正	[2π rad]	[deg]	Δphase		極性
+ 0 turn	0.8856	318.8	-41.2		IN
+ 1 turn	23.1936	69.7	69.7		IN
+ 2 turn	45.5016	180.6	0.6		OUT
+ 3 turn	67.8096	291.5	-68.5		IN
+ 4 turn	90.1176	42.3	42.3		IN
+ 5 turn	112.4256	153.2	-26.8		OUT
入射前補正	[2π rad]	[deg]	Δphase		極性
- 0 turn	21.4224	152.1	-27.9		OUT
- 1 turn	43.7304	262.9	82.9		OUT
- 2 turn	66.0384	13.8	13.8		IN
- 3 turn	88.3464	124.7	-55.3		OUT
- 4 turn	110.6544	235.6	55.6		OUT
- 5 turn	132.9624	346.5	-13.5		IN

遅い取り出し 8 GeV (COMET実験用)					
運転種別					
チューン Qx			22.32		
入射後補正	[2π rad]	[deg]	Δphase		極性
+ 0 turn	0.8892	320.1	-39.9		IN
+ 1 turn	23.2092	75.3	75.3		IN
+ 2 turn	45.5292	190.5	10.5		OUT
+ 3 turn	67.8492	305.7	-54.3		IN
+ 4 turn	90.1692	60.9	60.9		IN
+ 5 turn	112.4892	176.1	-3.9		OUT
入射前補正	[2π rad]	[deg]	Δphase		極性
- 0 turn	21.4308	155.1	-24.9		OUT
- 1 turn	43.7508	270.3	-89.7		IN
- 2 turn	66.0708	25.5	25.5		IN
- 3 turn	88.3908	140.7	-39.3		OUT
- 4 turn	110.7108	255.9	75.9		OUT
- 5 turn	133.0308	11.1	11.1		IN

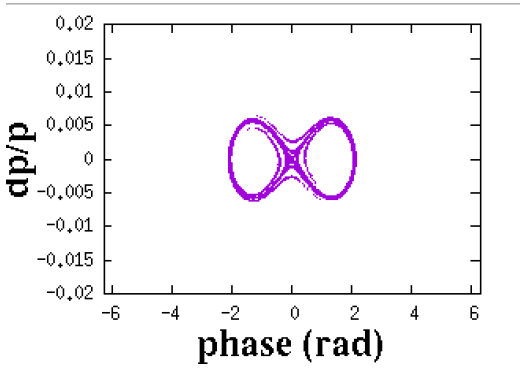
既存の設定
1番目に良い
1番目に良い

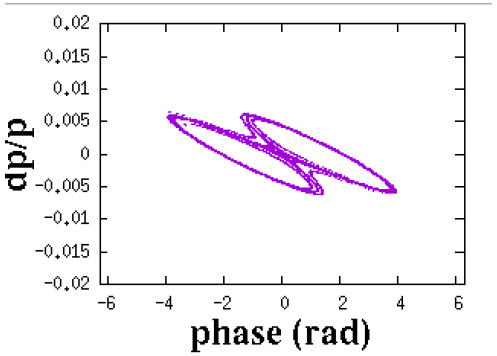
COMET-I:
CKMs will fire at 2 turn
after injection kicker timing
(phase advance 10.5deg
@Qx=22.32)

Further Mitigations of debunch Instability in the next RUN

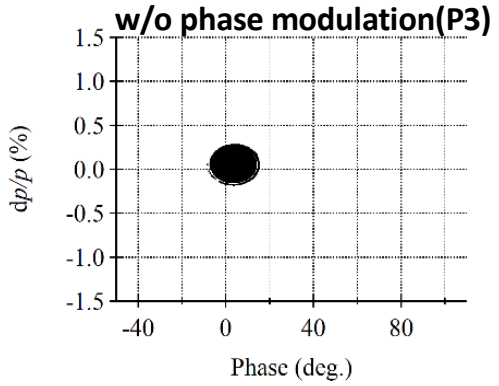
0. RF Phase offset injection tuning
1. Vertical TRF during debunch （Preliminary)
2. RF Phase offset injection + w/ second harmonic RF @ top -> debunch
3. RF Phase offset injection +fundamental RF with phase modulation in ACC. -> debunch
4. Slippage change by optics change

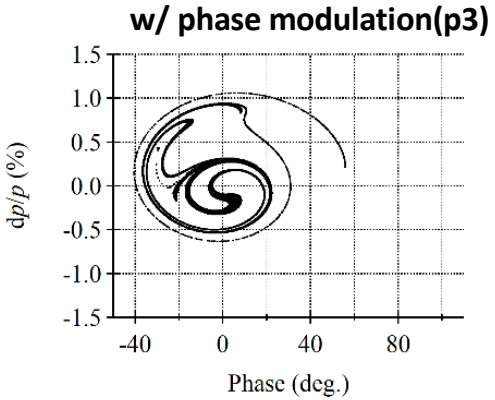
(option: Phase offset injection -> dp/p offset and second h. injection)





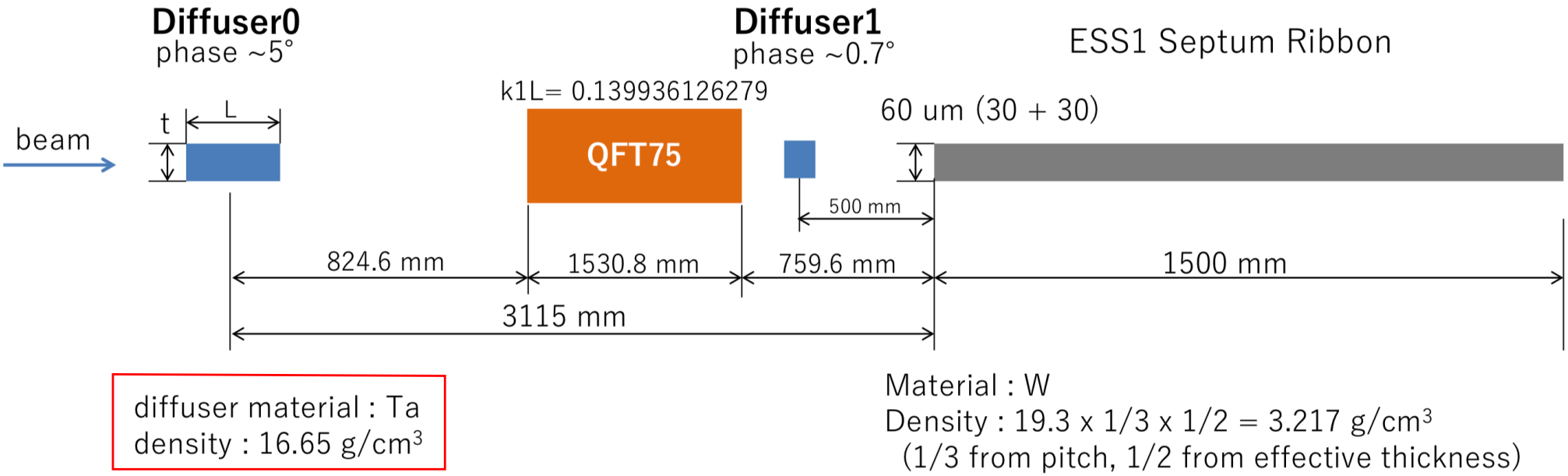
Y. Sugiyama





Y. Morita

Two Diffusers



Predictions by FLUKA (R. Muto)

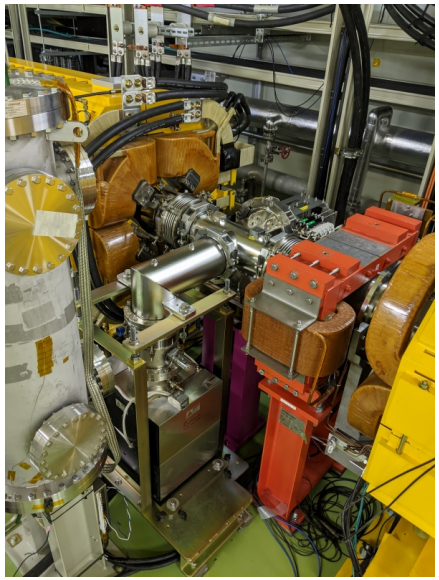
2020.11.12

	diff t [um]	diff0 L [mm]	diff1 t [um]	diff1 L [mm]	beam loss
diff0 only	200	0.5	-	-	0.42
diff1 only	-	-	100	2	0.47
diff0 and 1	200	0.5	100	2	0.35

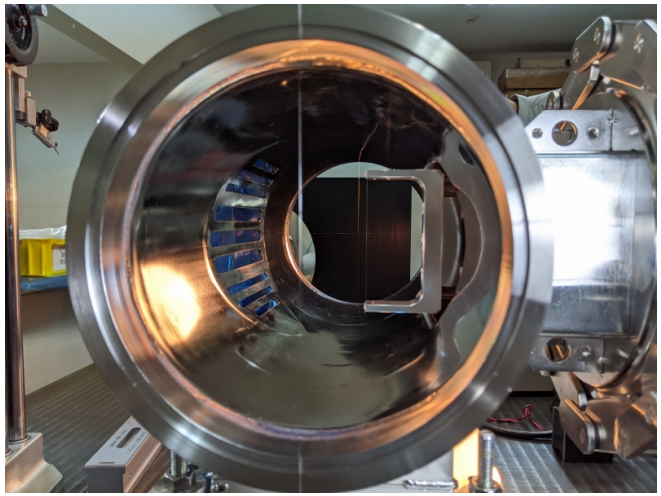
1.0 is ordinary SX

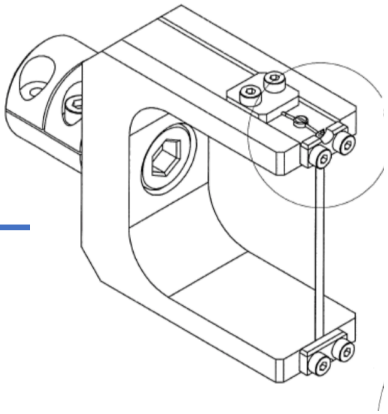
Two Diffusers Installation (Oct. 2020)

Diffuser0 t 0.2mm L:0.5mm tantalum



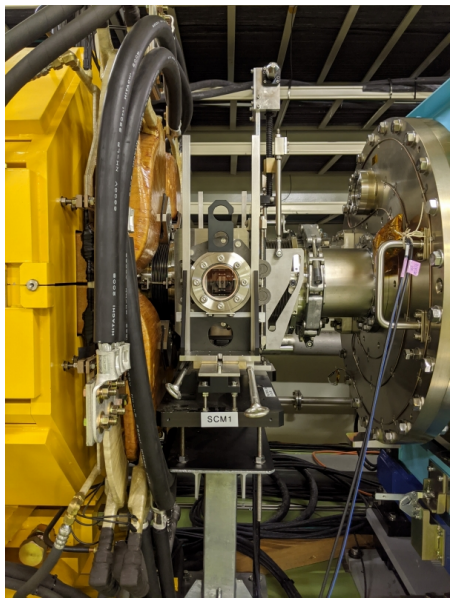
The vessel and mover are new

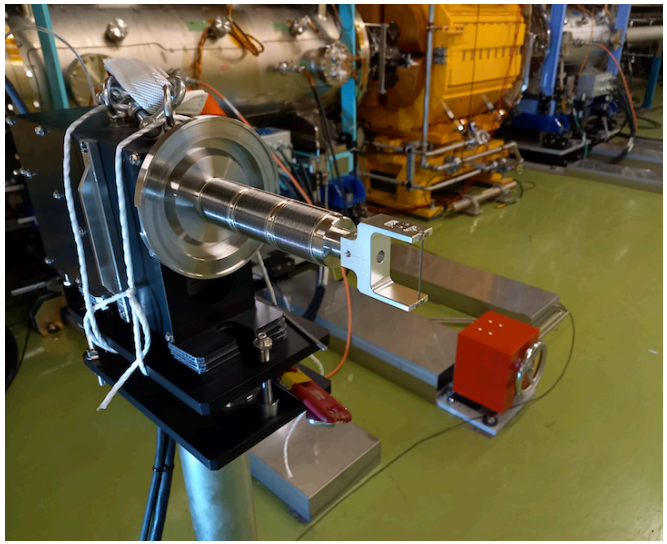




Diffuser1 t 0.1mm L:2mm tantalum

The vessel and mover for a screen monitor are reused





Next Slow Extraction Plans

◎ 30GeV SX Schedule

・Dec. 10 → Dec. 22, 2020　30 GeV SX

year-end , new year: beam stop

・Jan. 12 → Feb. 3, 2021　　30 GeV SX

◎ 30GeV Operation Topics

・Suppressing debunch instability、 Spill spike in B Line 、 V-position drift

・Beam power 50kW -> 60 kW

・Diffuser, TRF FB and ripple canceler tests　in the last 16 hours

◎ 8 GeV SX test for COMET

Feb. 4　→　Feb. 10

・10^{-11} extinction in all K1 to K4

・Reducing beam loss at ESS2