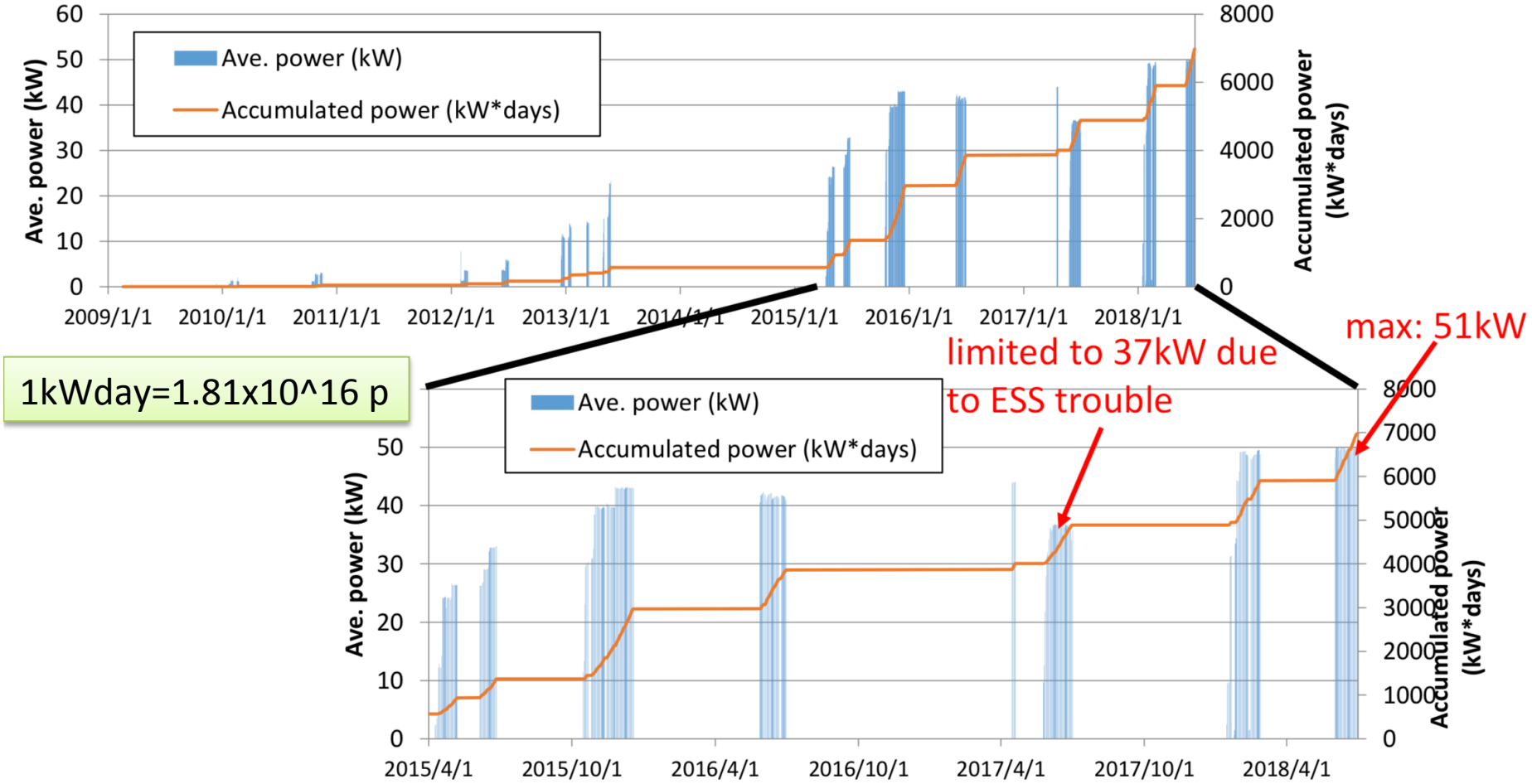
J-PARC SX Status

Jan. 14, 2019, SLAC

KEK/J-PARC
M.Tomizawa

Short review of J-PARC Slow Extraction
Status of beam performances
Plans

Development of Beam Intensity



1kWday=1.81x10^16 p

Accumulated beam time and intensity for HD

※spill: # of beam shots to HD

Before accident (Feb, 2009 – May, 2013): 1.26×10^6 spills, 560 kW*day

Before previous PAC (Apr, 2015 – Jun, 2017): 1.82×10^6 spills, 4241 kW*days

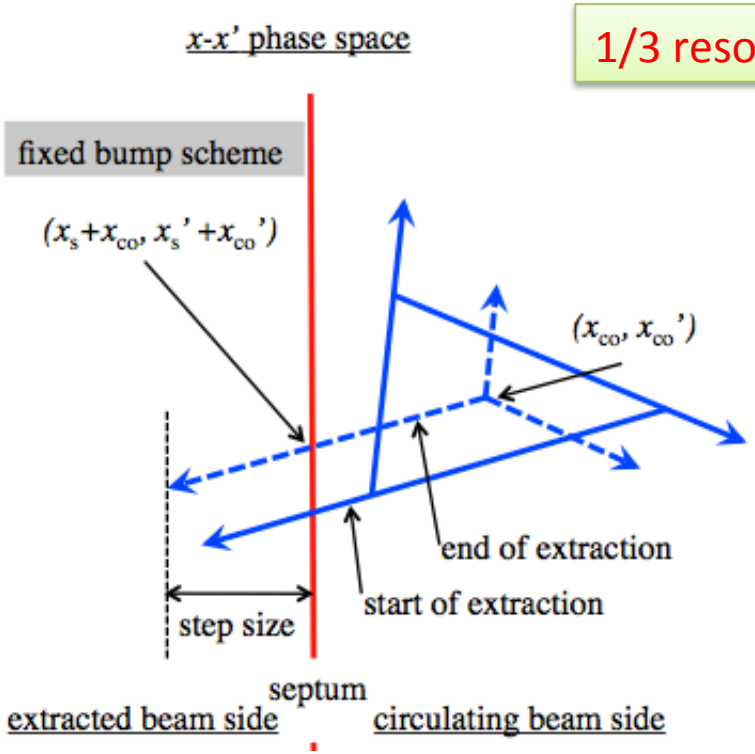
This period (Jan, 2018 – Jun, 2018): 0.75×10^6 spills, 2085 kW*days

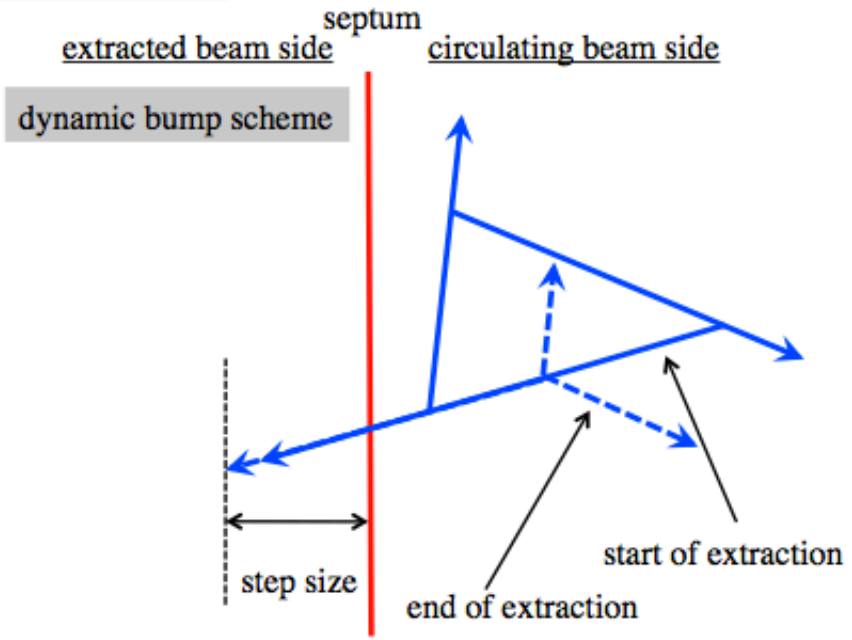
Schemes for Very High Extraction Efficiency (low beam loss)

◎Electrostatic Septum (ESS) QF-QF high β (small α) 40m
-> large step size (20mm)

◎dispersion free at ESS + low horizontal chromaticity
-> Separatrix is independent of $\Delta p/p$
depends on tune (constant resonant sextupole)

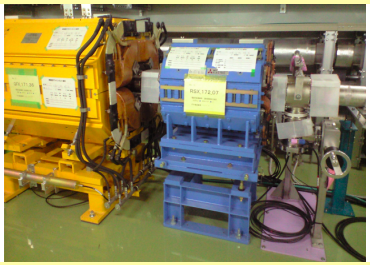
1/3 resonant extraction



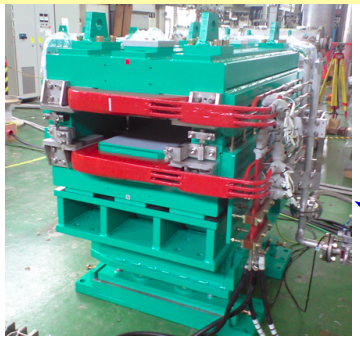


J-PARC Slow Extraction

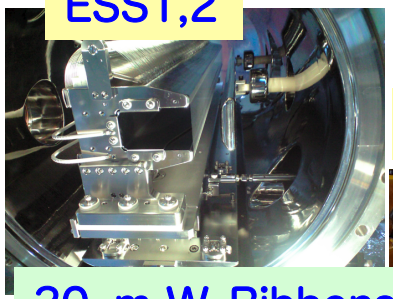
Resonant Sextupoles (8)



Bump magnets (4)



ESS1,2



30μm W-Ribbons (thickness 30μm)

EQ1,2

SX collimators

RQ

SMS11-12

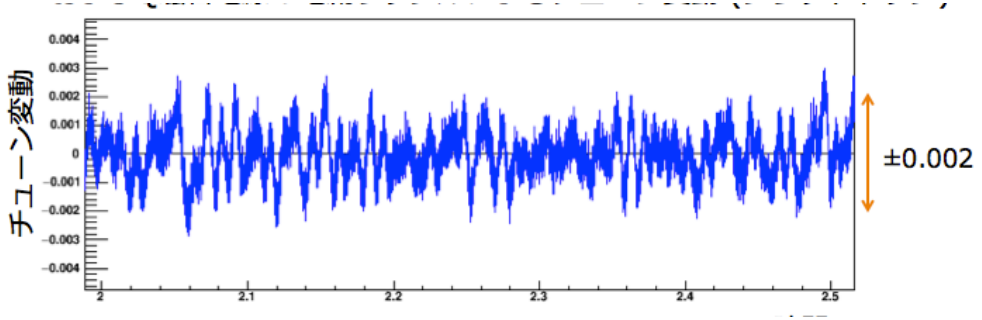
SMS21-24

SMS31,32

SMS33,34

Beam Spill Regulations

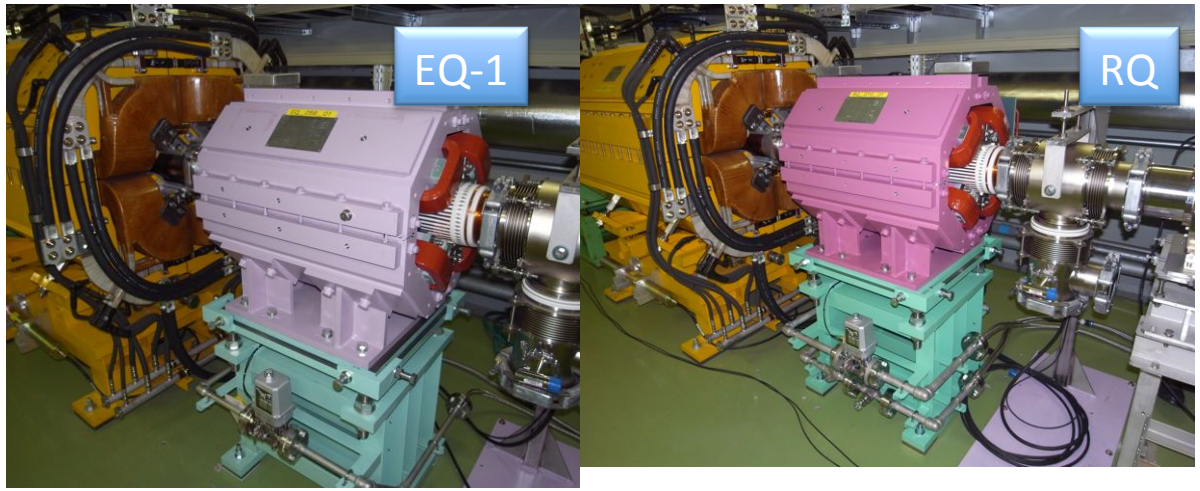
◯ BMs and QMs P.S. current ripples $\Delta I/I$ 10^{-4} each

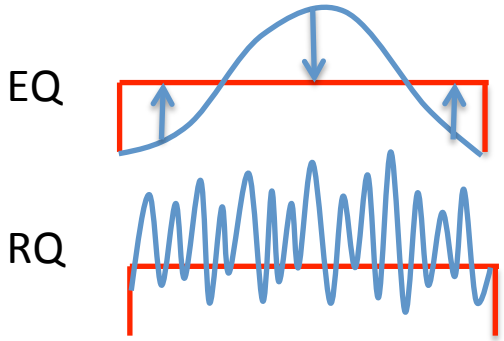


◯48 QFNs in arcs are linearly ramped to the 67/3 resonance

◯Feedback by EQ1 and EQ2 makes a rectangular spill shape

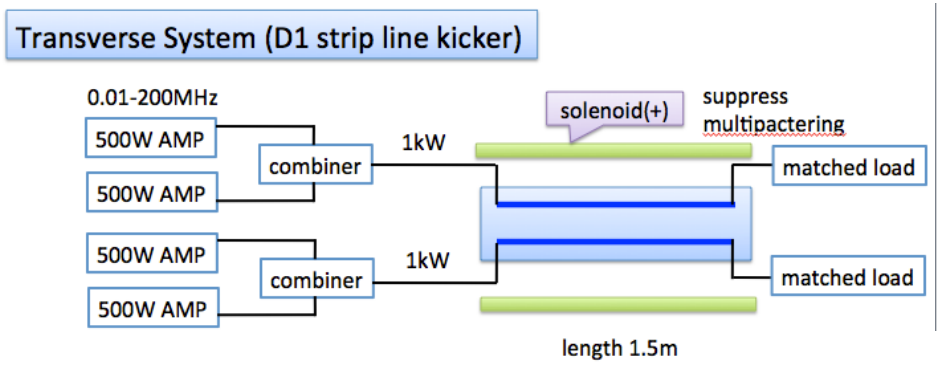
◯Feedback by Fast response RQ improves a spill ripple.

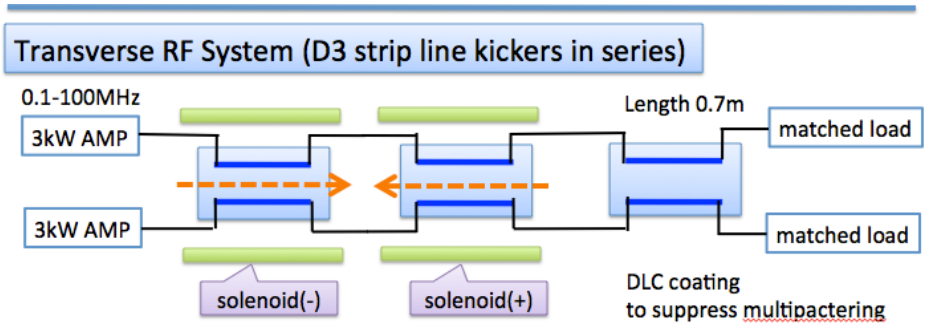




Transverse RF (RF knockout)

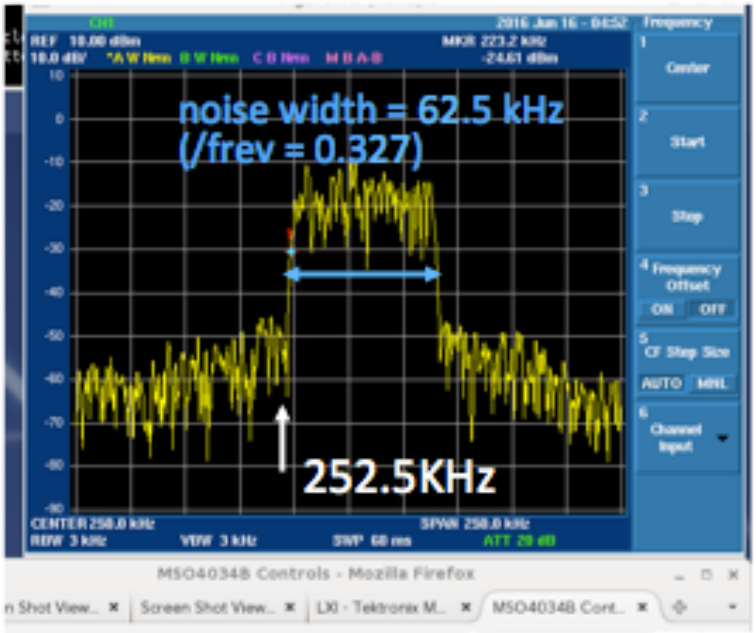
applied to the circulating beam (no Feedback)





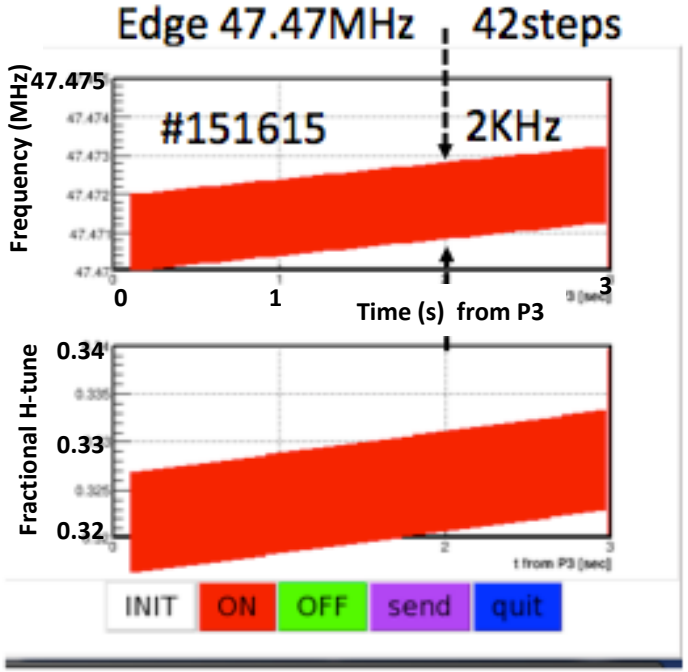
Qx=22.3333

D1 strip line kicker



H-tune: 0.320-0.648

D3 strip line kicker



frv=0.191167438MHz

TRF ON
EQ,RQ ON

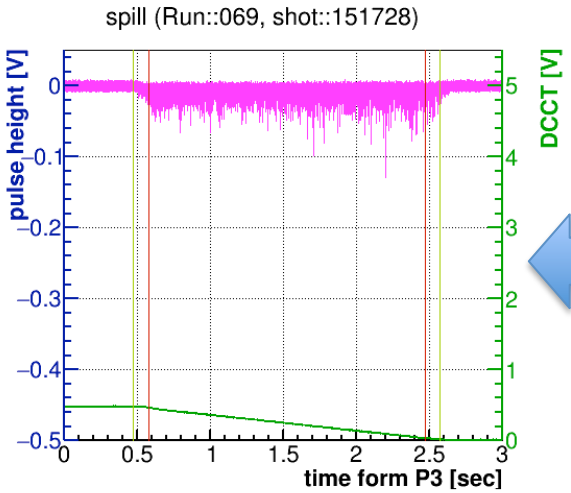
#151728

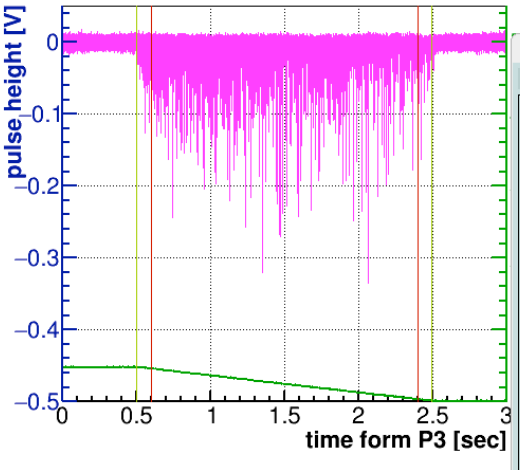
TRF OFF
EQ,RQ ON

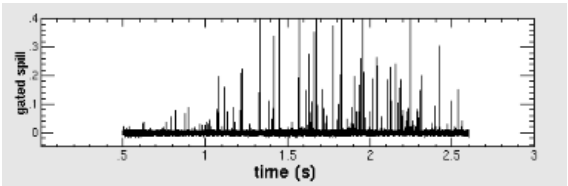
41kW

6/15 #151515

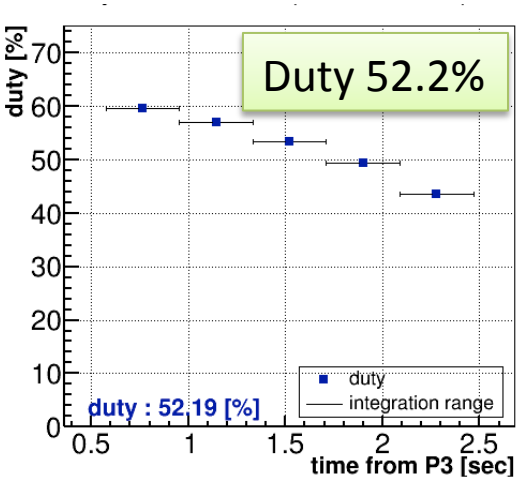
w/o EQ,RQ

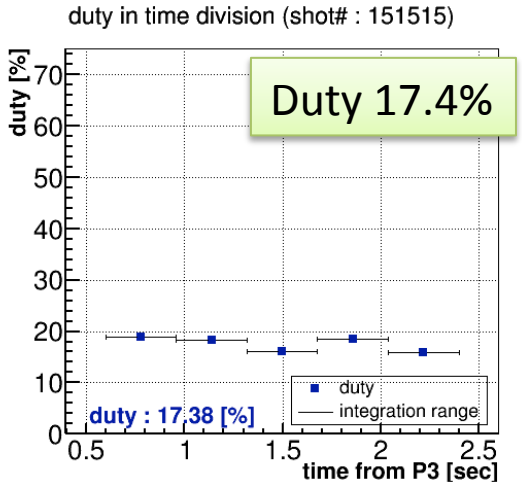






Duty 2-3%



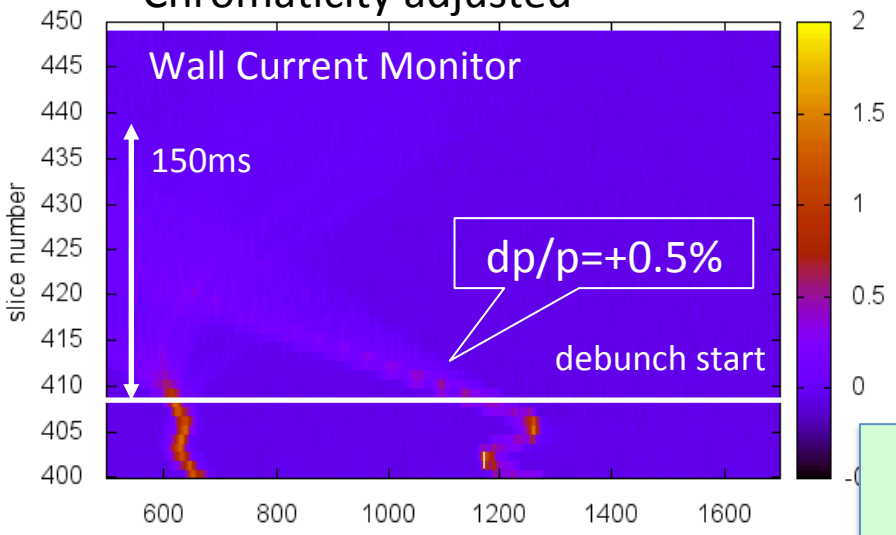


$$Spill\,Duty\,Factor = \left[\int_0^T I(t)dt\right]^2 \Big/ \left[\int_0^T dt \cdot \int_0^T I^2(t)dt\right]$$

ideal spill -> 100%

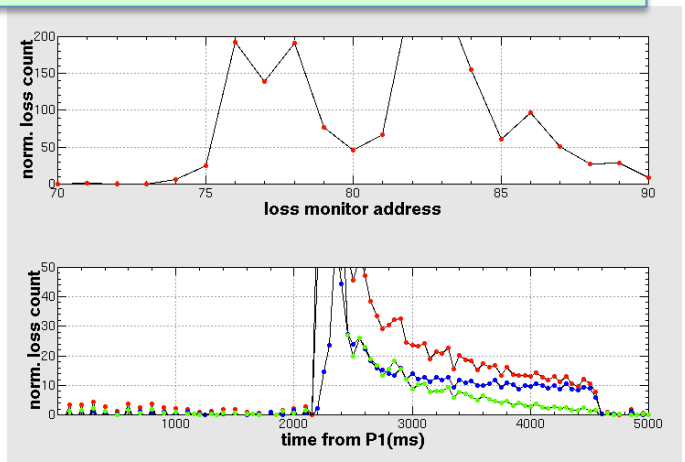
Beam Instability during debunching

6/9, 2015
33.1kW (4.1x10^13 ppp)
RF phase offset 0°
Chromaticity adjusted



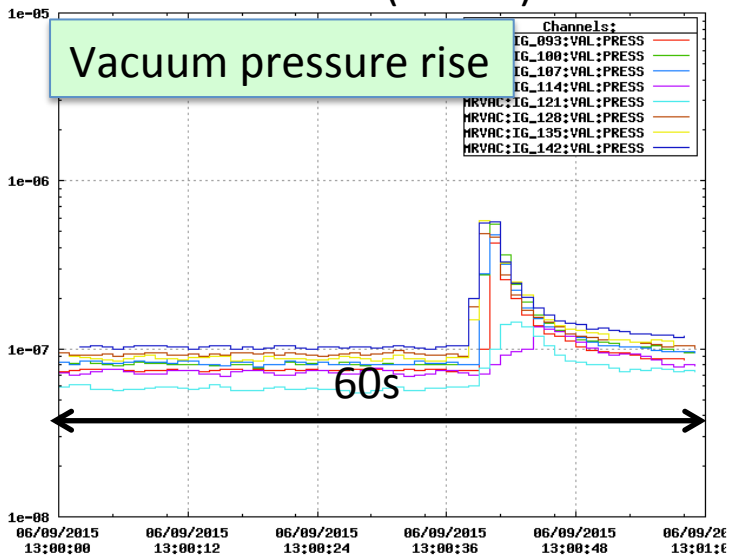
Large beam loss in slow extraction

Efficiency
97.14%

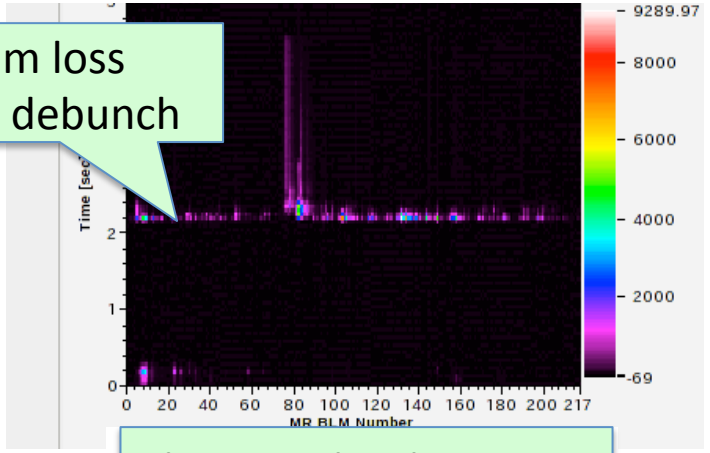


Vacuum (ARC-B)

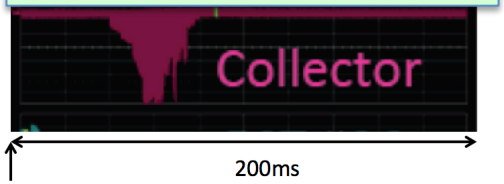
Vacuum pressure rise



Beam loss during debunch



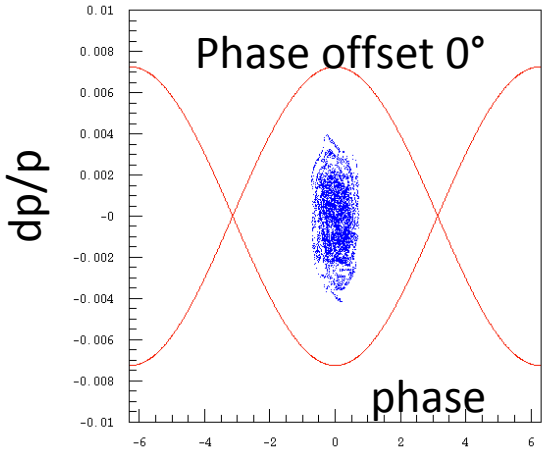
Electron cloud monitor

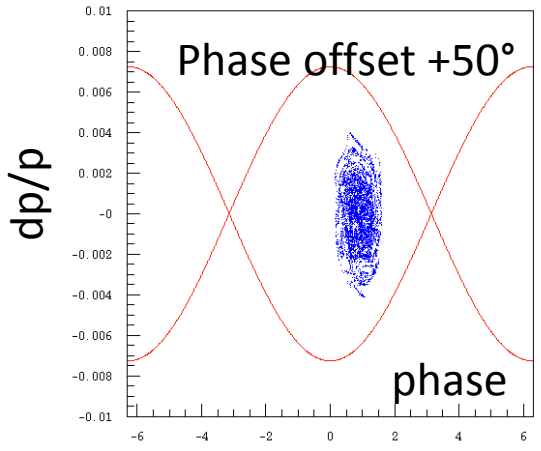


Beam Instability Mitigation

Phase offset injection into RF bucket

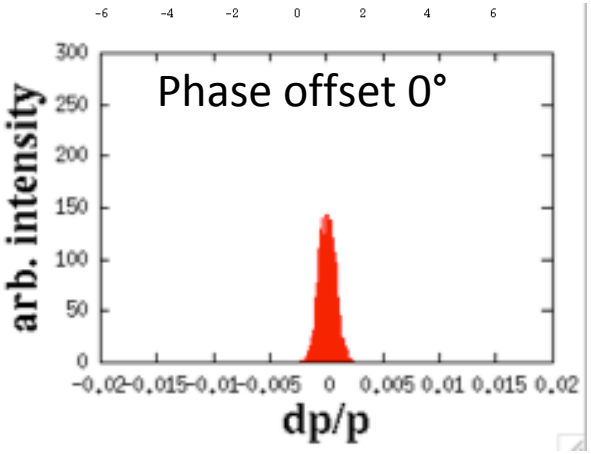
160kV
Injection

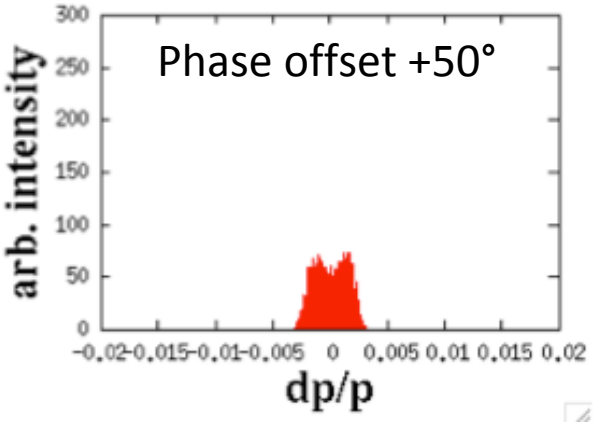




Dipole oscillation
Smear

256kV
Flat top
Before debunch





This mitigation is essential to achieve the present beam power and reduce at the beginning of the acceleration

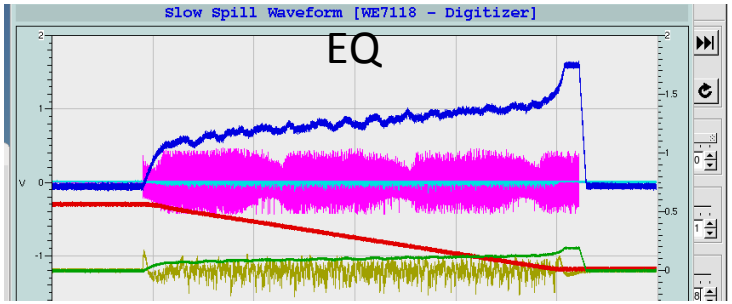
30 GeV Slow Extraction (RUN78)

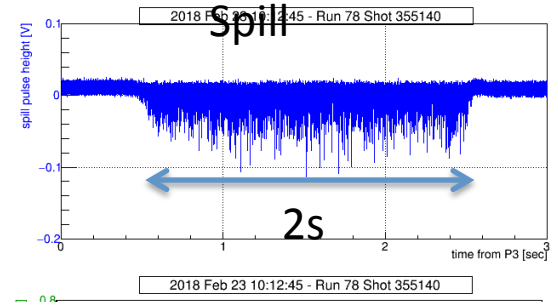
Shot 355150
51.09 kW

Rep. rate 5.20 s (<- 5.52s)
flat top is 2.61 s (<- 2.93 s)

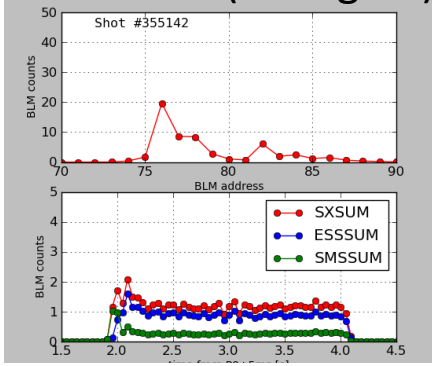
2/23 10:13

5.6x10^13 ppp
RF phase offset 50 deg
Efficiency 99.52%
Spill Duty 48%
Spill length 2.05s

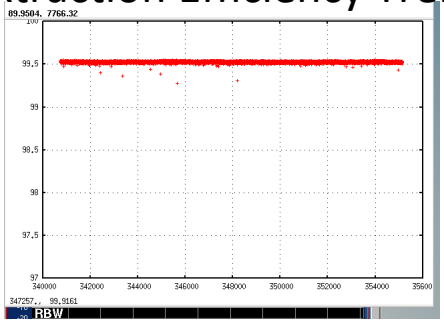


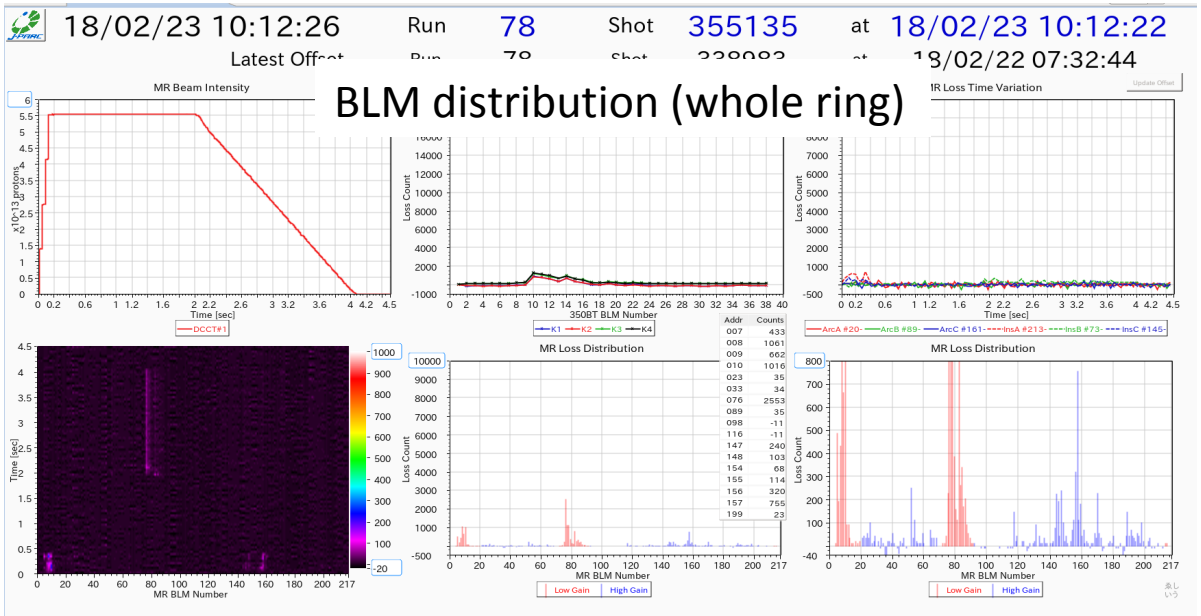


Beam Loss (SX region)



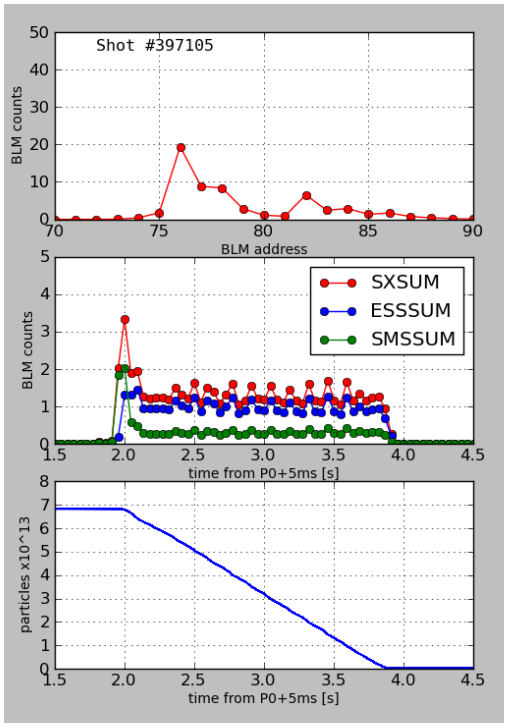
Extraction Efficiency Trend

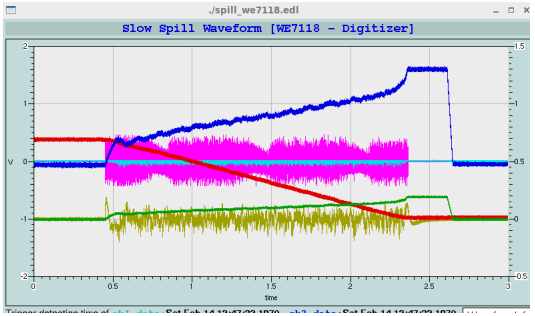


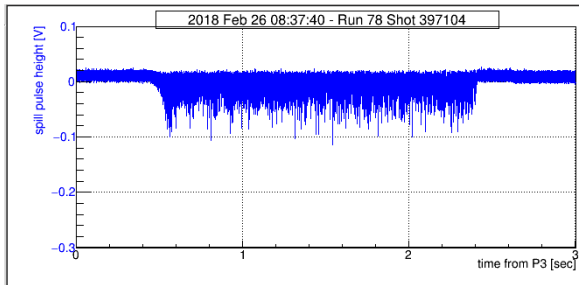


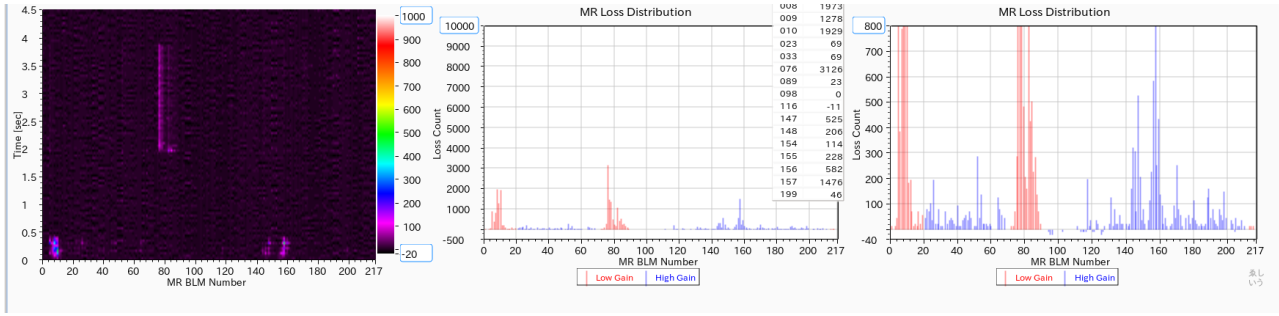
Higher Power SX Demonstration (2 shots)

Beam power 62.8kW (rep. 5.2s)
6.8x10^13 ppp
Efficiency 99.47%
Spill Duty 56%
Spill length 1.82s
RF phase offset 50deg





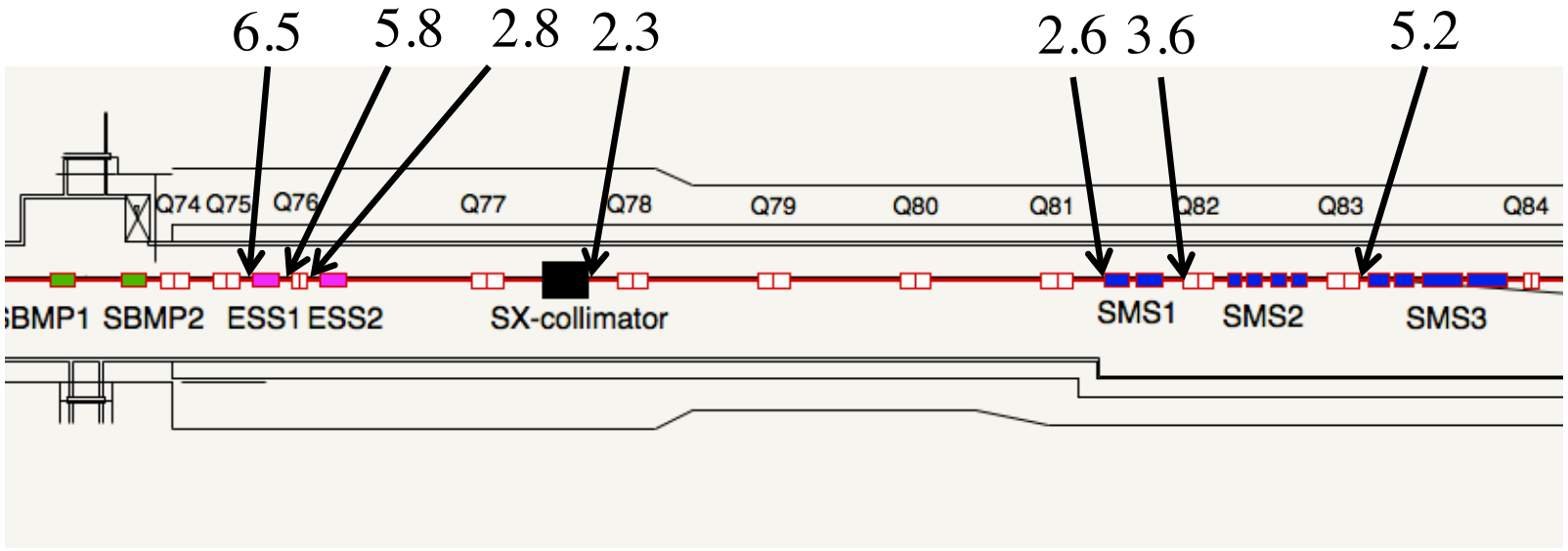




Residual Radiation

Unit: mSv/h Residual dose on contact 6/7 2018

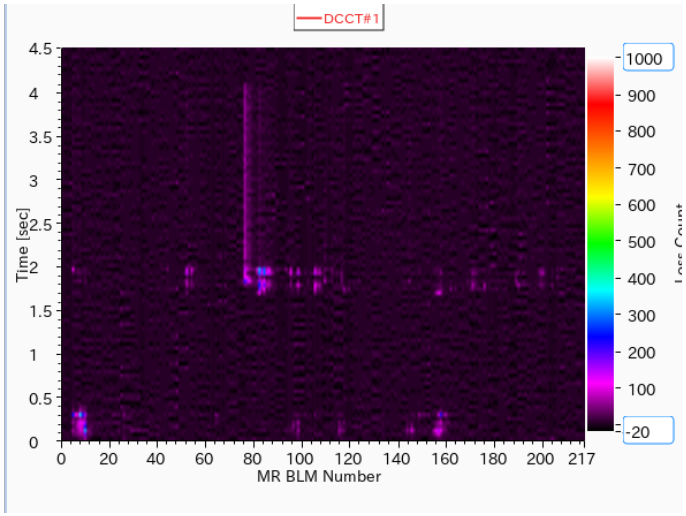
6.5 h cooling after 51 kW SX operation

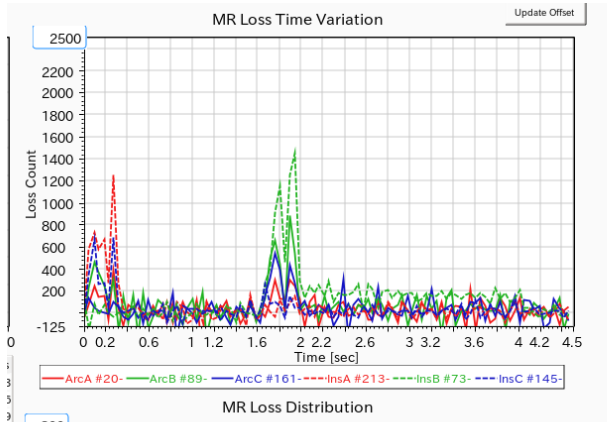


Instability during debunch

The Instability was not enough mitigated at 50° phase offset at RUN 79

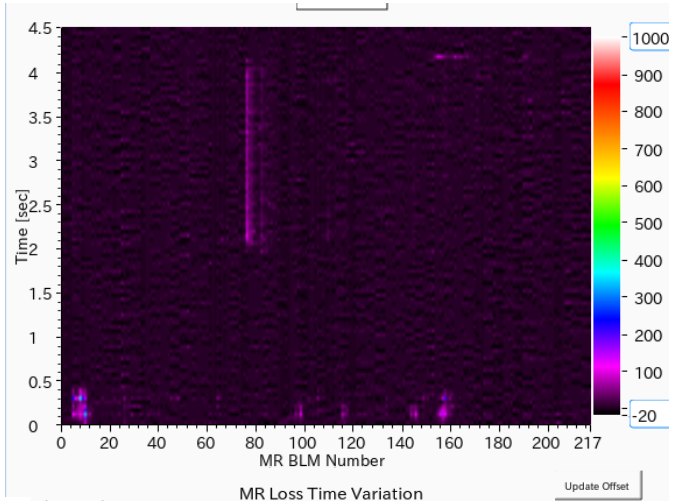
w/ Instability
51kW SX
RF phase offset 50°
6/1 #1495161
Efficiency 99.08%

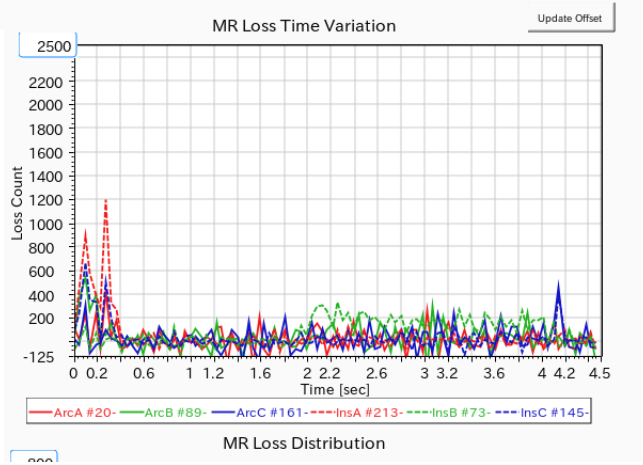




(TRF調整前)

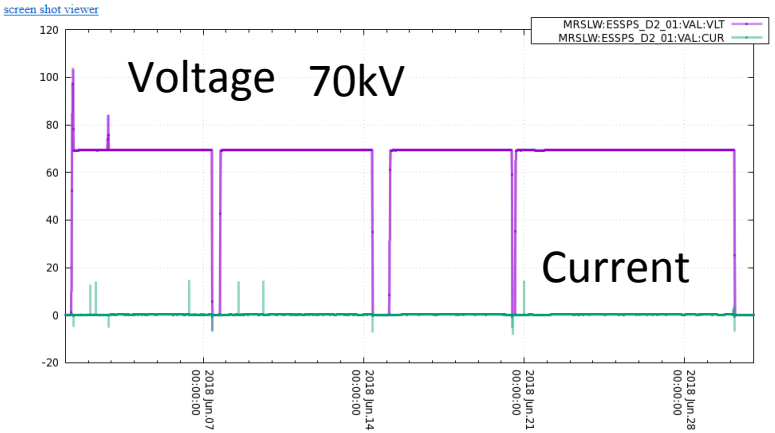
w/o Instability
51kW SX
RF phase offset 55°
6/1 #1495201
Efficiency 99.48% (5shots av.)

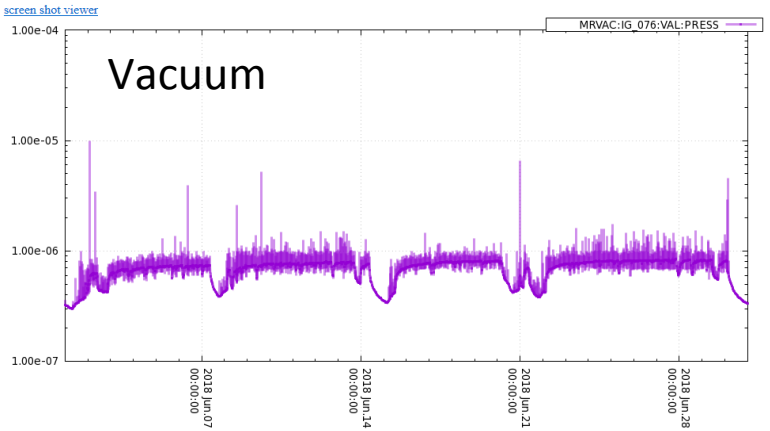




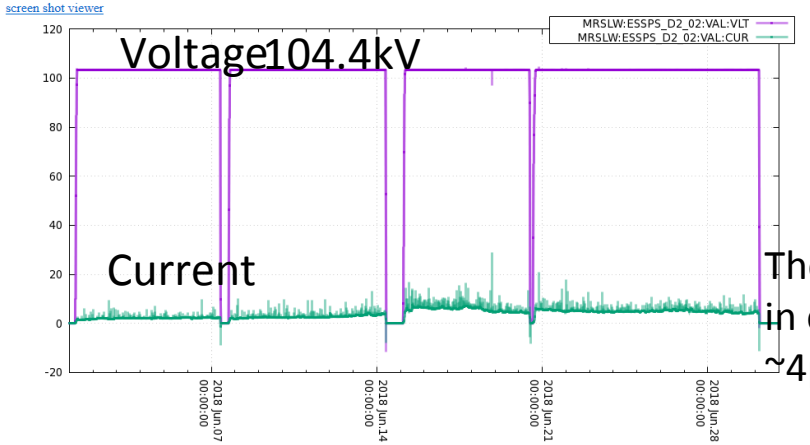
Jun 1th, 2018~Jun 30th, 2018 (RUN79)

ESS1

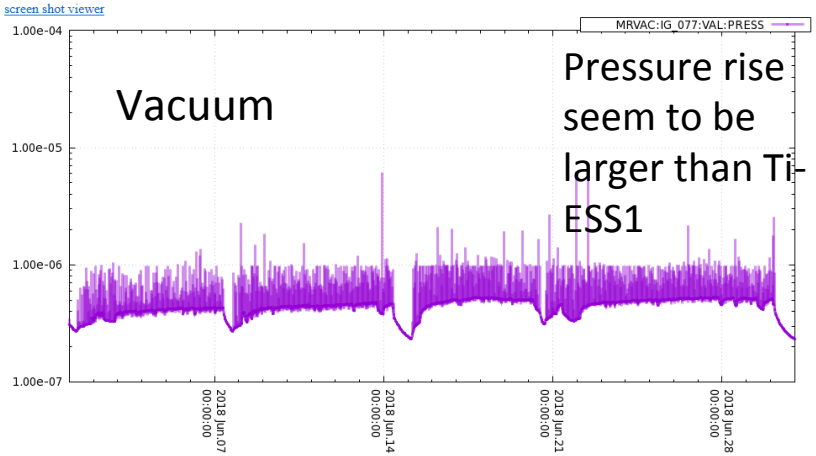




ESS2



The current in end is ~4μA



Tried operation at 104.4 kV nominal voltage,
extraction efficeincy slightly reduced, need more tuning.

Next J-PARC SX RUN

Linac beam peak current has been changed from 40mA to 50mA

◎ Feb. 8 th - March 25 th, 2019

First 5 days（～11h x 5)

- Beam recovery to 50kW
- Instability mitigation Study
- Spill regulation study

(1-2kW beam power-up study may be scheduled after these studies)

◎ April 1 st - April 25 th, 2019

End of this run 17h

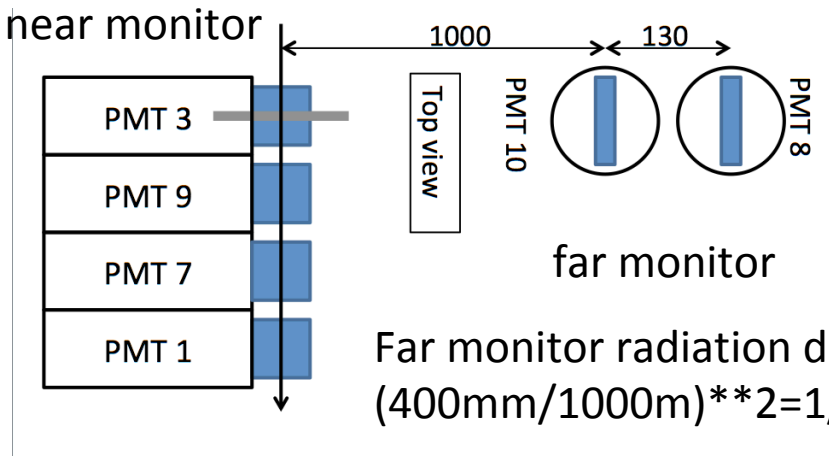
- Study toward higher beam power
- Spill regulation study

◎ instability mitigation study (debunched beam is dumped by kickers w/o SX)

- RCS injection painting >50pi and O.P.
- RF phase jump to unstable fix point -> debunch
- MR injection errors
- TRF ON during debunch (de-coherence)
- higher RF voltage and larger RF phase offset at injection

◎ Spill regulation study

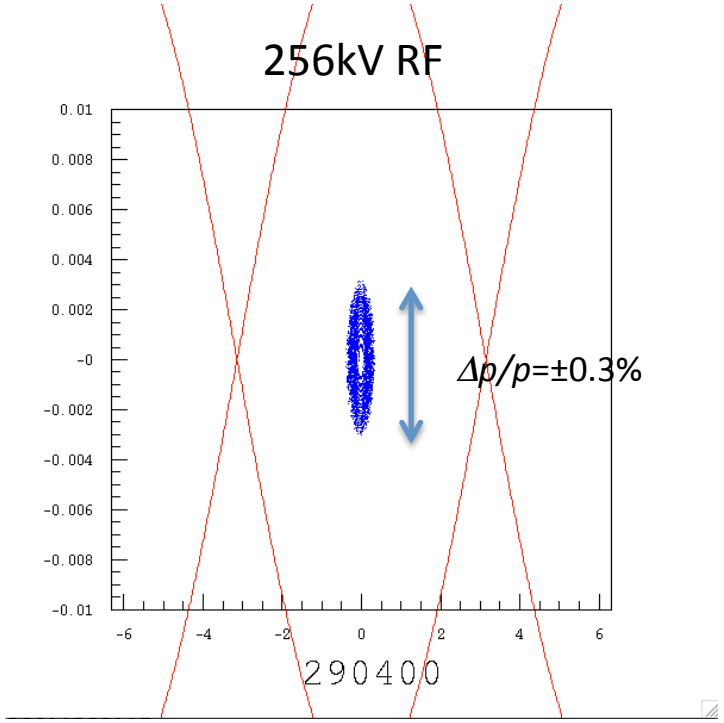
- spill monitor： far side monitor is expected to be used for physics run. coincidence, diamond detector test
- spill feedback 、TRF、ripple canceler Study and their combination Study
- TRF feedback test

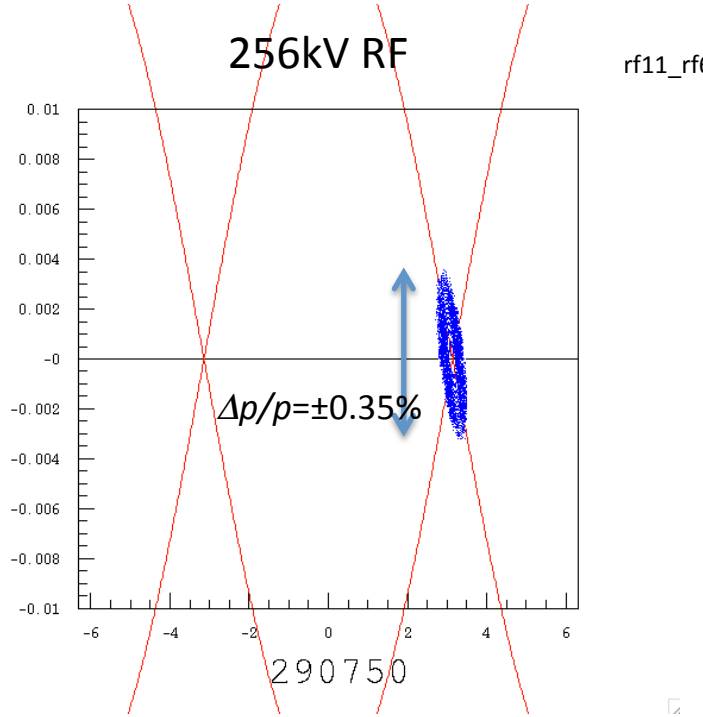


Far monitor radiation damage reduces to
(400mm/1000m)**2=1/6.25

Further Mitigation Plans of the instability during debunch

◎debunch after RF phase jump at flat top





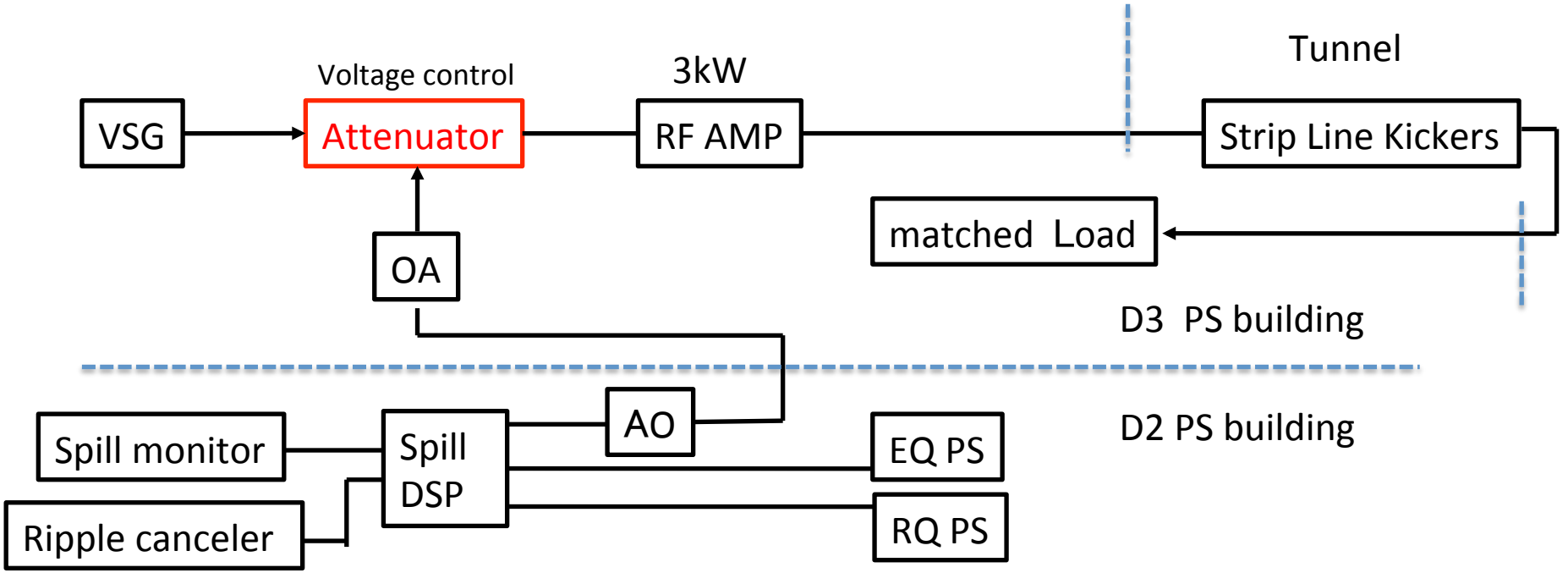
rf11_rf6_010_26.com

Combination with RF phase offset

◎VHF cavities: uniform and enlarge longitudinal emittance

Transverse RF feedback

Schematic block diagram

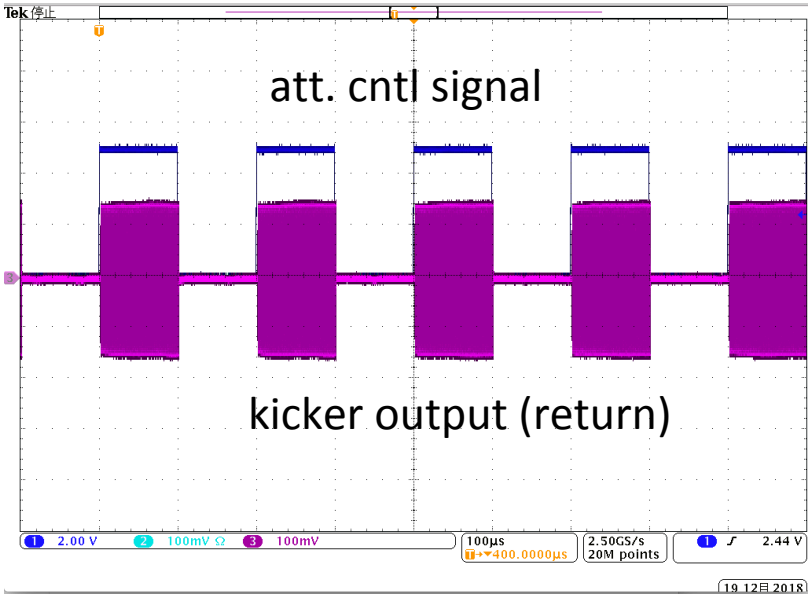


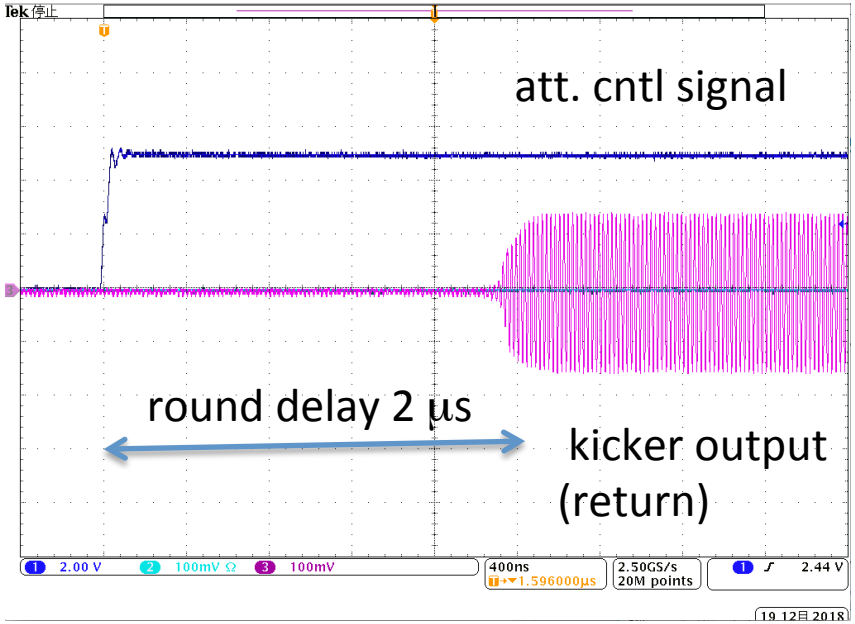
Spill monitor signal: for spill feedback
Ripple canceler signal : for spill feed-forward
Vector Signal Generator: for spill feed-forward
Attenuator: for spill feedback
TRF can be applied for both feedback and feed-forward

Pulsed TRF test by attenuator for TRF feedback

VSG -3dbm
Control 0-5V, 5KHz
w/o RF noise f=47.47219057 MHz
ON 2.5s OFF 2.5s

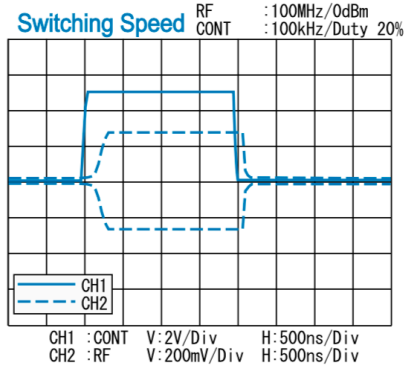
matched load monitor





3kW, 10 KHz rep. is also OK

attenuator delay 300ns



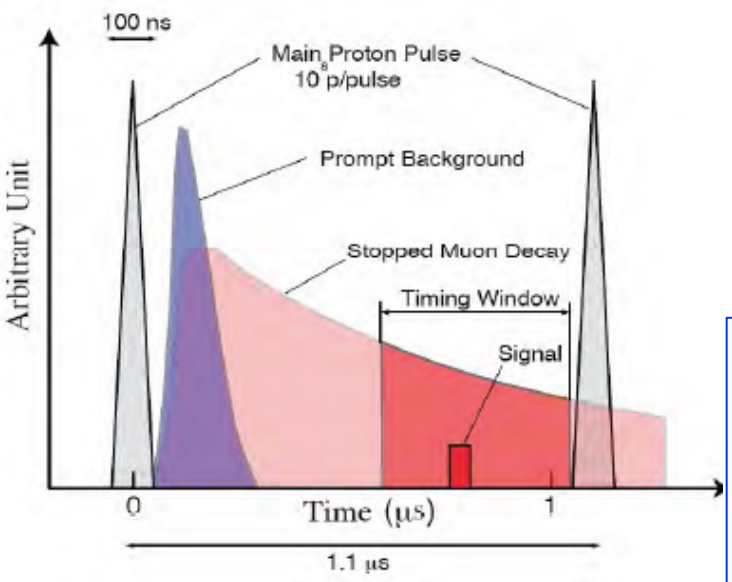
8 GeV SE for COMET

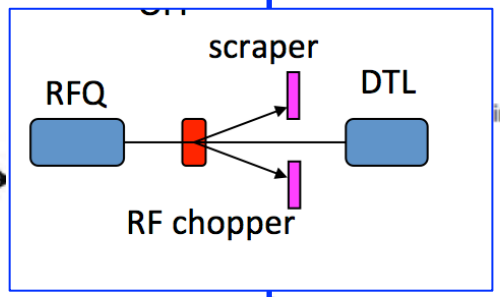
(COherent Muon to Electron Transition)

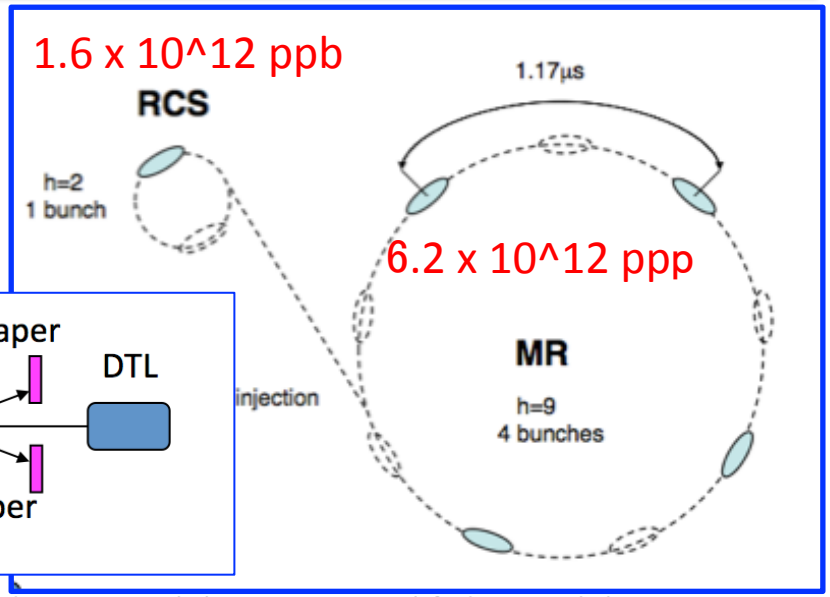
searches muon to an electron conversion event (LFV)

8GeV 1MHz pulsed beam

RCS 1 bunch acceleration
4 (or3) bunches are injected and SE in MR
COMET phase-I 3.2kW (2.48 s cycle)



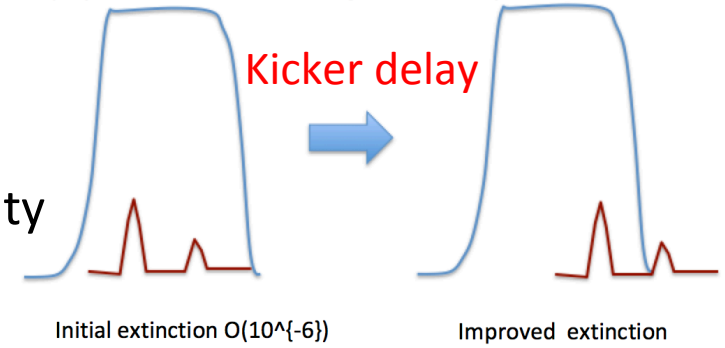




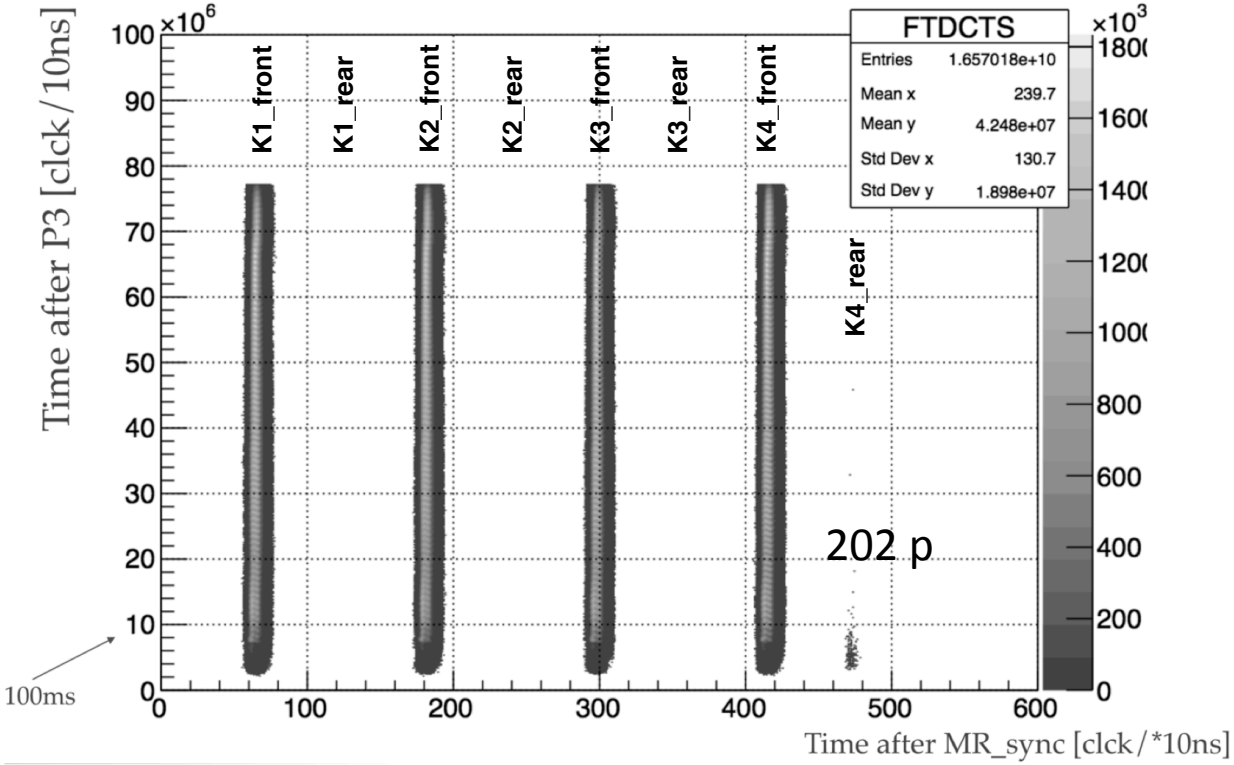
Ordinary injection kicker wave timing Shifted injection kicker wave timing

◎8 GeV SE adiabatic dumping is small aperture of magnetic septa

◎Ratio of inter-bunchs and main bunch intensity
Extinction < 10^{-9}

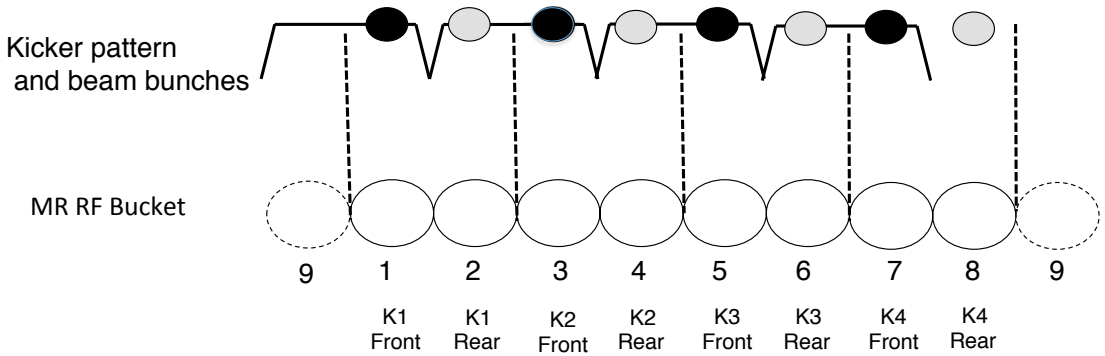


Measured time structure of 8 GeV bunched SE beam



K1-K3:
Zero signal (<1 event
extinction < 6.0E-11

K4:
202 events



CNT wire Fabrication and Test

Previous:

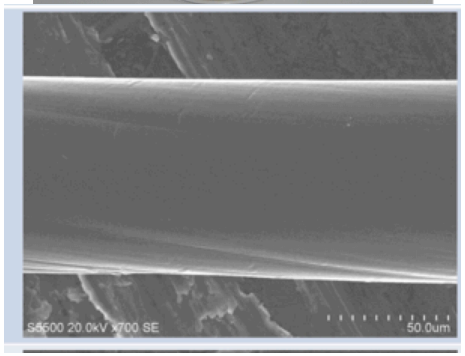
Diameter ϕ50 μm

breaking load av. 0.84N (0.43GPa)

New:

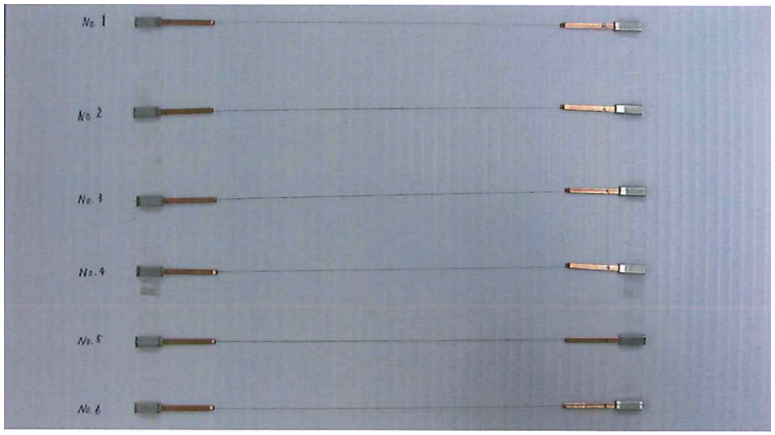
Diameter ϕ76～80 μm

breaking load 3.3N～3.5N (～0.7 GPa)

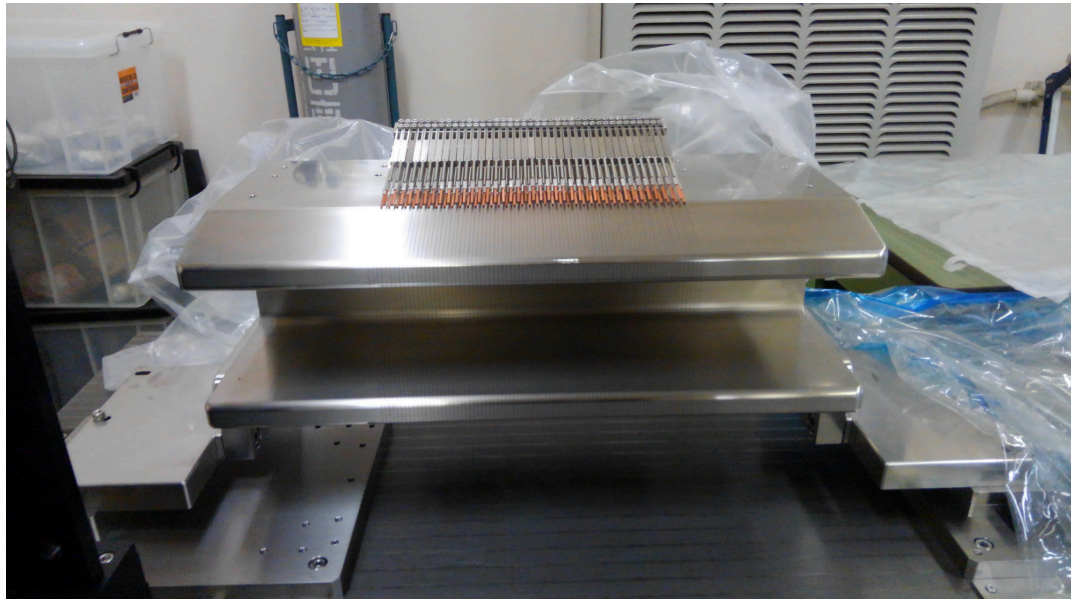


50m x 3 wires will be soon ordered

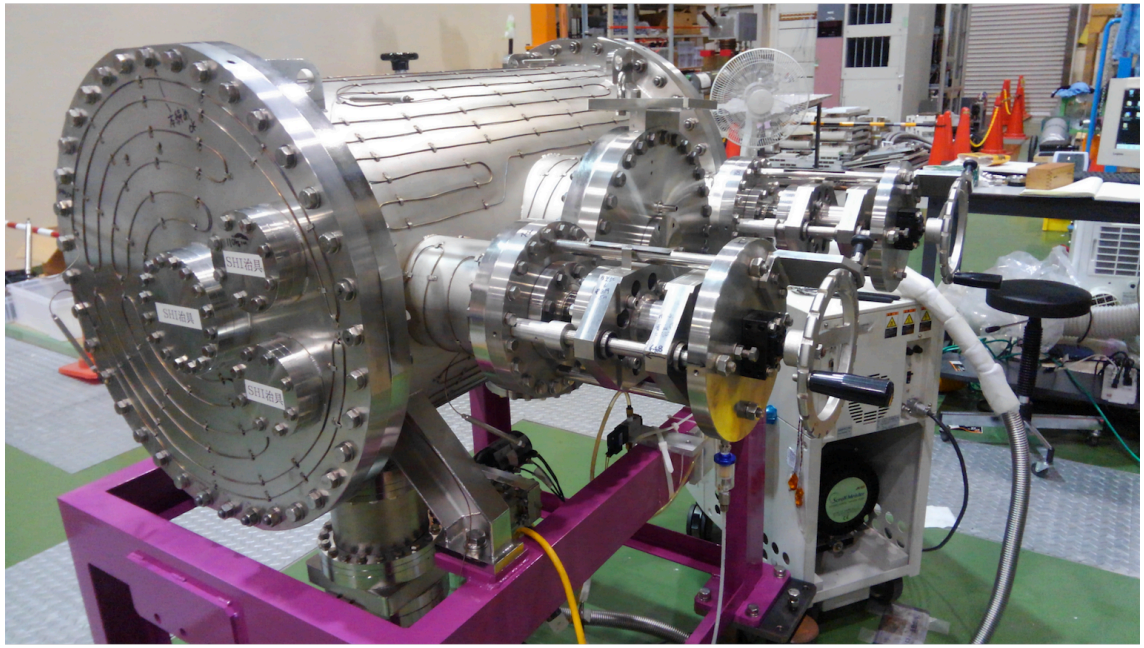
ϕ90 μm CNT preliminary crimping test



Crimping test of new wires will soon start



50cm yoke to strain CNT wires
(ϕ150 μm CF wires)



70 cm R&D SUS chamber
for CNT high voltage test

moved to the test space
In J-PARC
Feedthrough HV test
Will soon start.

Beam power ramp-up plans for SX

◯ ・51 kW is beam power limit due to present target capacity (administrative 53.3kW)
・The target will be upgraded to 80-90 kW (administrative)

◯ We will Increase proton numbers stored in the ring
to 70 kW (7.6x10^13 ppp) at 5.2 s cycle (62.8 kW = 6.8x10^13 demonstrated)
We have already succeeded to suppress the instability at 7.6x10^13 (66.3kW at rep. 5.52s)
at phase offset of 60 deg. w/o SE

◯ BM and QM power supply upgrade (2021)
・ Rep. 2.48s -> 1.3 s (FX, neutrino T2K)
・ flat top 2.63s -> 2.43 s (not to shorten spill length)
Rep. 1.3 + 2.43 =3.73 s (SX)
5.2/3.73 *70 kW -> 98 kW ~100kW

◯ Ideas to reduce a beam loss and an exposure for maintenance workers
・ESS with a titanium vessel decrease residual dose . First ESS done, Second is planned
・Diffusers/scatterer upstream of the ESS
・Carbon nanotube ESS R&D
・Local shield for maintenance