J-PARC related Accelerator Topics

Beam Monitor G, Acc. Div., J-PARC(KEK)
Kenichirou Satou

CERN-KEK Committee, 14th Meeting
Meeting Room Large (KEK Building no.2)
16:20~16:40, 18/11/2019

Contents

- Present list of collaboration
- New abort beam dump collaboration
  - Progress of design works
- RF collaboration
  - Rad-hard Solid State Amplifier (SSA) for Fast feedback system
- Beam monitor collaboration
  - IPM
  - BBQ
  - Timepix3 based BLM
- Slow extraction collaboration
  - Slow-beam loss reduction by Diffuser/Crystal
- Summary

Present list of collaboration: J-PARC MR - CERN

- Items in collaborations (including in-kind contributions)
  - Abort beam dump (Started from 2018)
    - Discussions on new abort dump
  - RF (Started from 2012)
    - FINEMET Cavities for CERN PS, PSB: “KEK Participation in the LIU” presented by C. Ohmori
    - Fast feedback system
  - Beam Monitor (Started from 2014 Nov.)
    - Ionization Profile Monitor (IPM) for CERN PS (from 2014)
    - Fast beam loss monitor based on Timepix3 (from 2019)
  - Slow extraction (Started from 2019 Spring)
    - Crystal and diffuser system
- New MOU was setup

//Beam dynamics study(beam instrumentation), beam intercepting devices (targets, window, collimator, beam dump), RF system as well as high intensity beam targets facility//

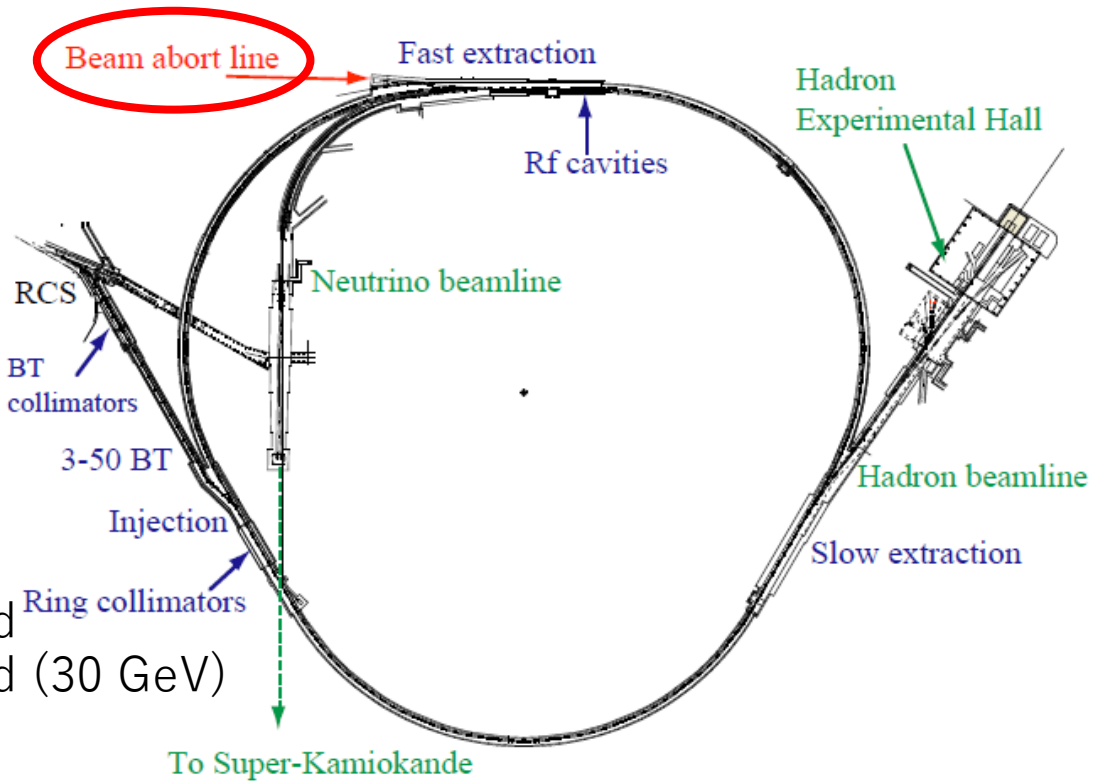
- Workshop for CERN/J-PARC KEK collaboration @ CERN
  - 10, 11/Oct. 2019, 24 talks including 3 talks from J-PARC MR by M. Yoshii, M. Shirakata, and K. Satou
  - Beam Monitor, RF system, Beam abort dump system were discussed

New abort beam dump collaboration

- J-PARC: Masashi Shirakata
- CERN: Simone Gilardoni, Marco Calviani

Specification of J-PARC Main Ring

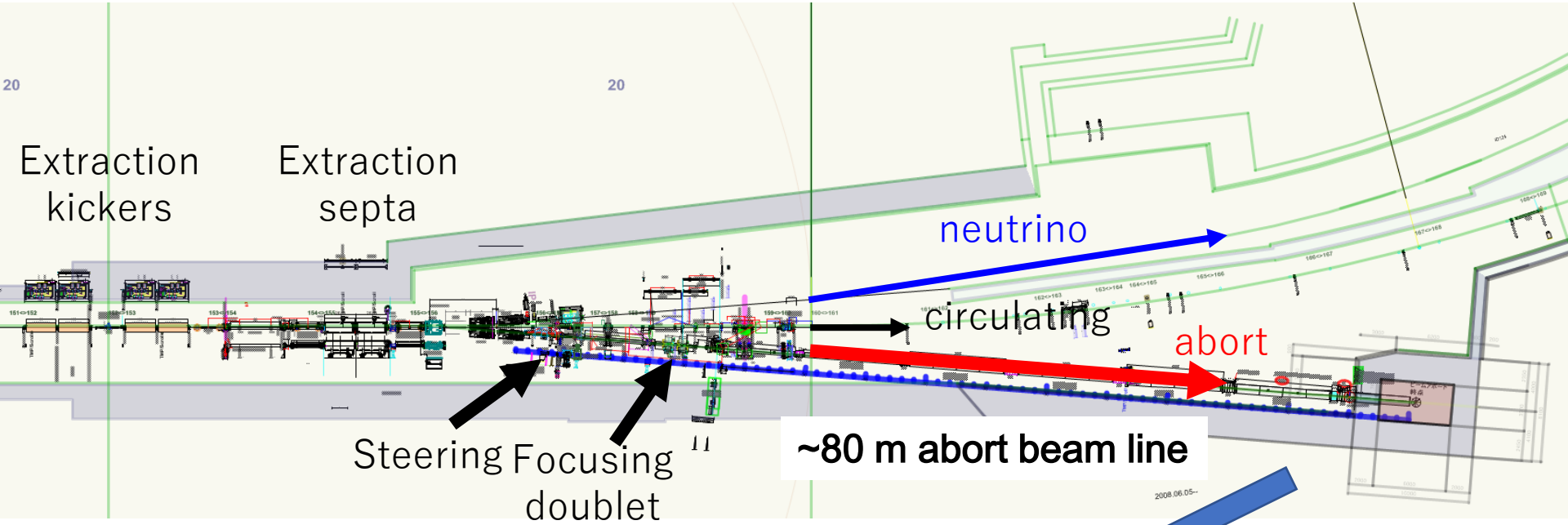
Circumference	1567.5 m
Repetition cycle	2.48 s / 5.58 s
Injection energy	3 GeV
Extraction energy	30 GeV
Superperiodicity	3
harmonic #	9
No of bunches	8
Transition γ	j 31.7
Typical tune	(22.40, 20.75)
Transverse emittance	
At injection	~54 π mm mrad
At extraction	~10 π mm mrad (30 GeV)

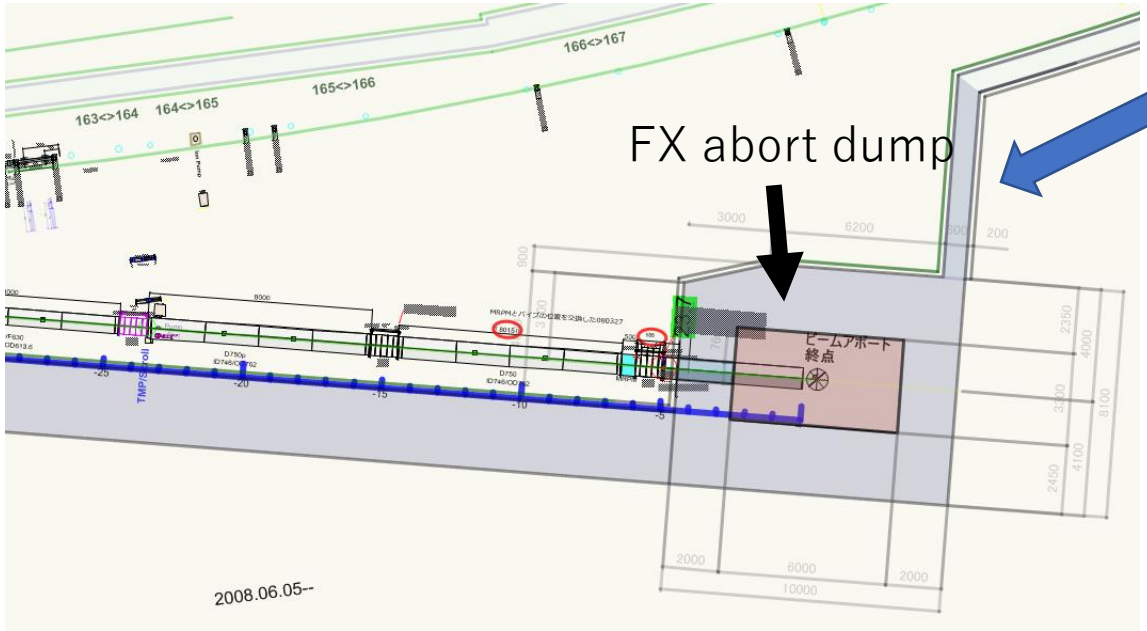


Three dispersion free straight sections of 116 m long:

- Injection and collimation systems
- Slow extraction(SX)
  to Hadron experimental Hall (Rare decay, hyper nucleus…)
- Rf cavities and Fast extraction(FX) (beam is extracted inside/outside of the ring)
  outside: Beam abort line
  inside: Neutrino beamline (intense ν beam is send to SK located 300 km west)

FX Beam Abort Line





FX abort dump
Iron block of 3.3 x 3.3 x 6 m
in the concrete wall

Present dump capacity: 7.5 kW

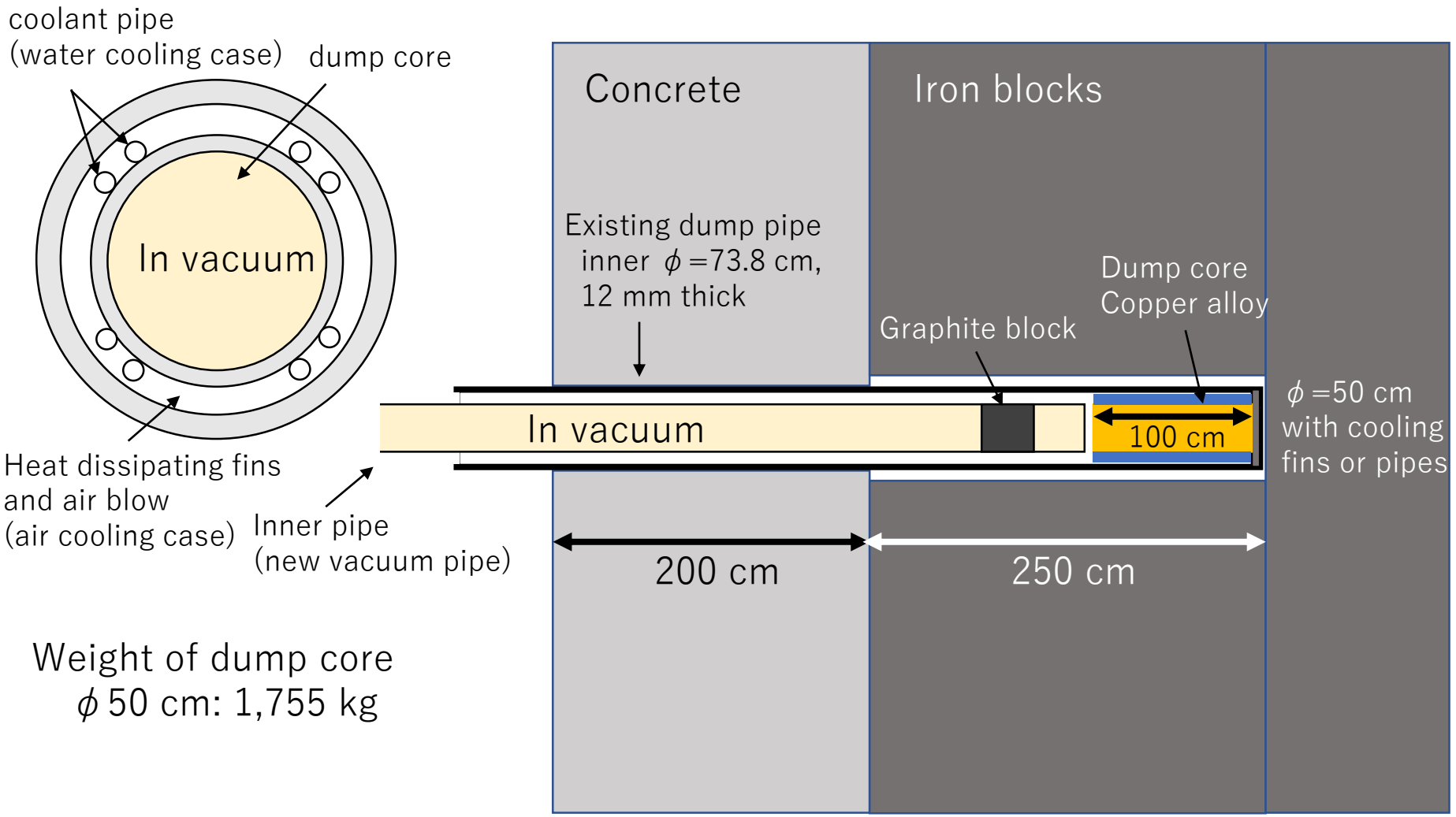
Only 18 shots for one hour for 500 kW high intensity beam

2018/12/11 M. J. Shirakata

Installation of the Dump Core (design base)

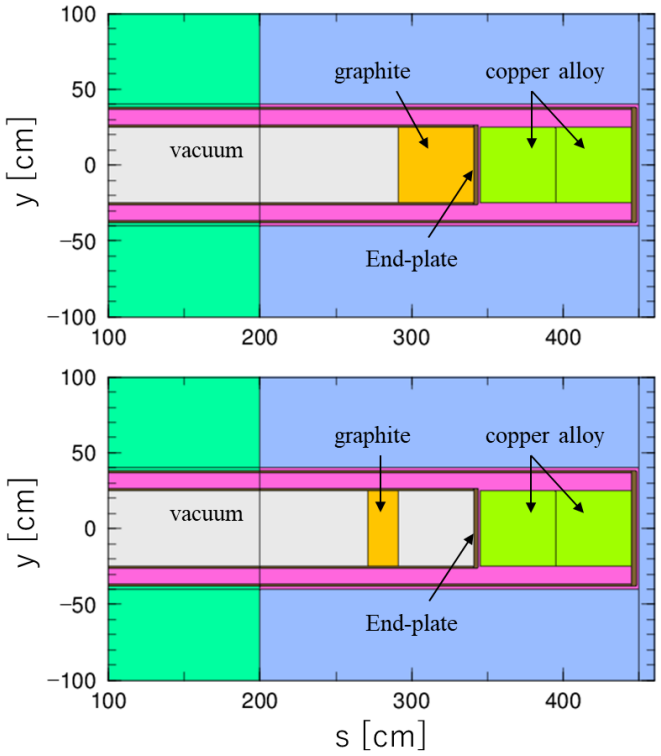
New dump scenario

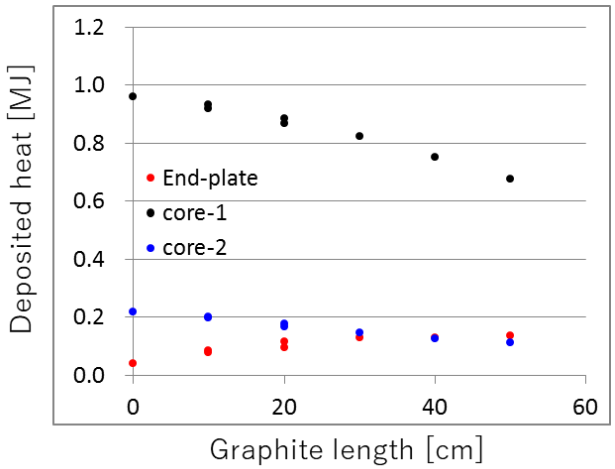
- **7.5kW -> 30kW**
- Copper alloy dump core is installed into the end of existing dump pipe.
- Inner pipe is also installed for the vacuum section.



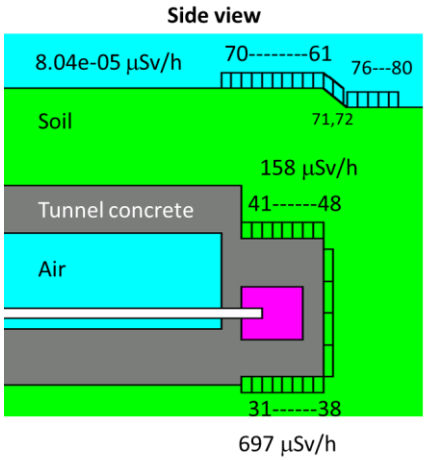
Weight of dump core
ϕ 50 cm: 1,755 kg

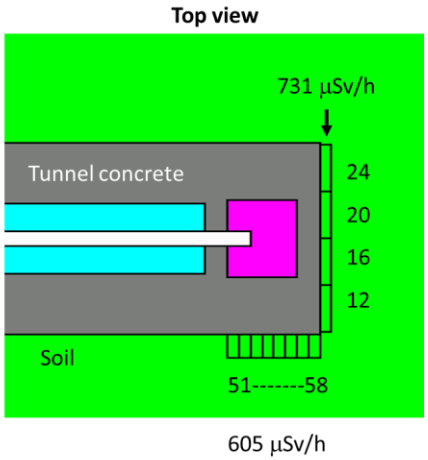
Heat deposit calculation for different configurations



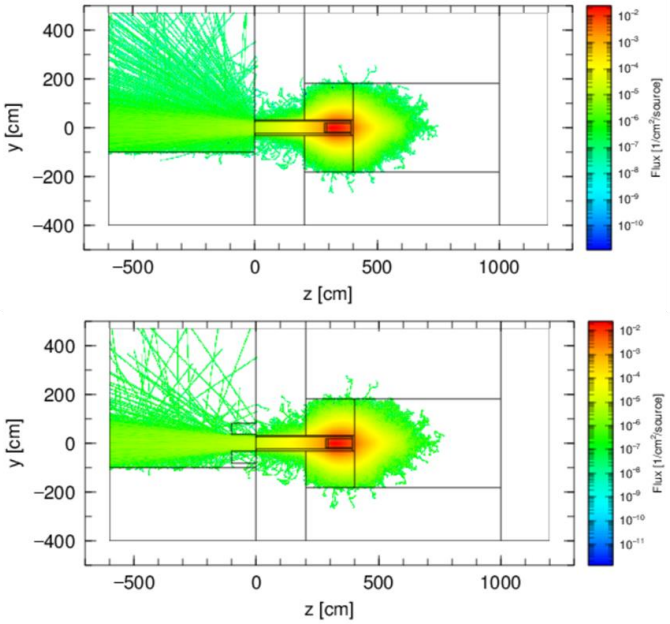


Dose estimation

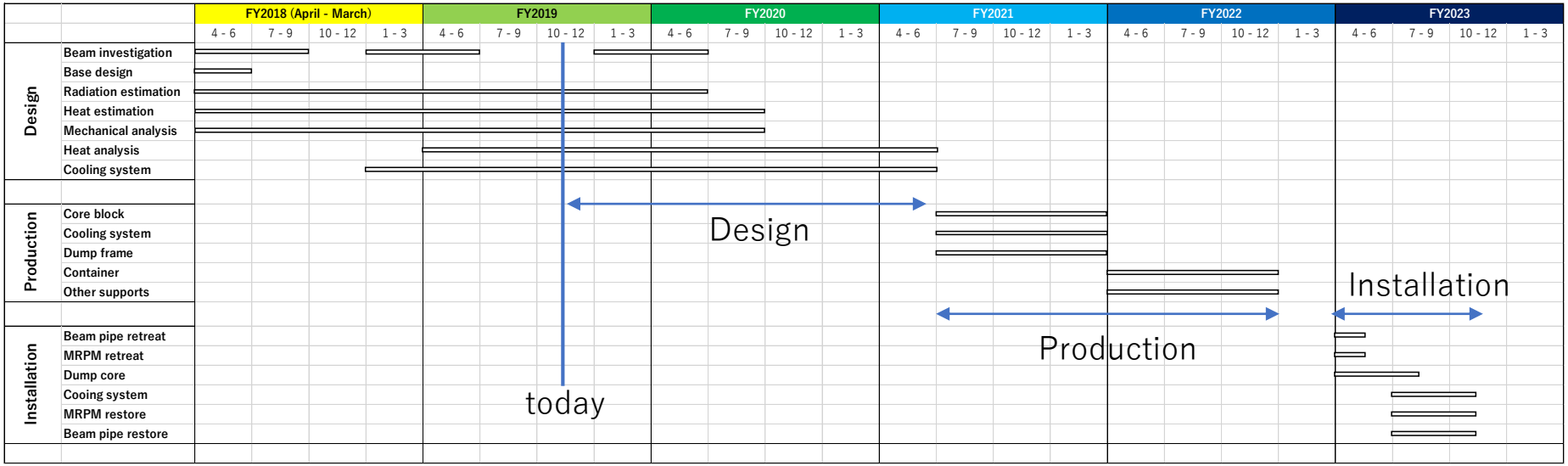




Neutron flux calculation



Schedule: X day is postponed by 2 years



Concept

- Dump beam power: 30kW
- Add graphite and cupper blocks
- Forced Air cooling
- Similar design as CERN PSB

Detail design works

1) Rough design: Almost finished
2) Radiation: Prompt dose check(PHITS) -> Almost finished
3) Static stress: In rough estimation -> finished
4) Thermal issues: Energy deposit (PHITS)
   Stress and Deformation (ANSYS)
5) Cooling method: Forced Air or water (ANSYS)
6) Radiation embrittlement: RADIATE collaboration

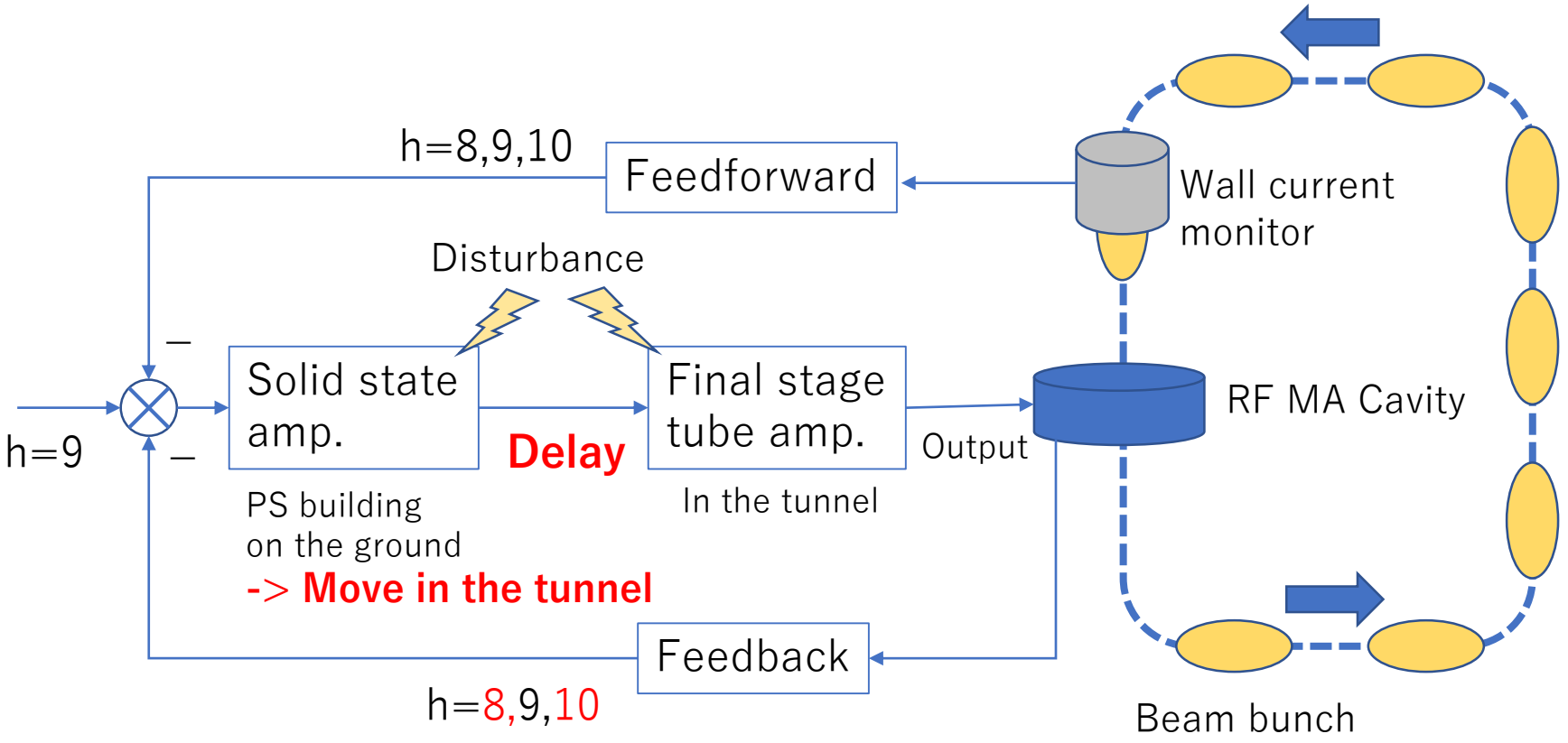
Need further discussions with and advises from CERN

Production and installation

RF collaboration

- J-PARC/KEK: Masahito Yoshii
- CERN: Mauro Paoluzzi

J-PARC MR RF system (Fund. h=9)



Present issues
1) Non-linearity of tube amp.
2) Detection errors of harmonics (Feedforward)
3) Feedforward system tuning depending on beam intensity

Solution: Fast feedback system
Move solid state amp. system in the tunnel to shorten the time delay to improve feedback

KEK Contribution to LIU-RF

- **KEK has contributed to RF upgrade of LIU.**
  - Replacements of **PS Booster RF system to wideband cavity system**.
  - Developments of **Damper cavity for longitudinal coupled bunch instability in PS**.
  - Developments of **Rad-Hard Solid-State Amplifiers (SSA)**
    - The SSA withstands 2kGy in hadron accelerator. -> Very long life in PSB
    - It also withstands 10 kGy by gamma-ray and next test in J-PARC is planned during LS2. -> Improvements of PS RF feedback

News

CERN Courier 2017 July-Aug.

HL-LHC

LHC luminosity upgrade accelerates

CERN has recently implemented two important steps towards the High Luminosity LHC (HL-LHC) – an upgrade that will increase the intensity of the LHC's collisions significantly from the early 2020s. Preparing CERN's existing accelerator complex to cope with more intense proton beams presents several challenges, in particular concerning the system that injects protons into the LHC.

At a ceremony on 9 May, a major new linear accelerator, Linac 4, was inaugurated. Replacing Linac 2, which had been in service since 1978, it is CERN's newest accelerator acquisition since the LHC and is due to feed the accelerator complex with higher-energy particle beams. After an extensive testing period, Linac 4 will be connected to the existing infrastructure during the long technical shutdown in 2019/2020.

To cope with the higher-intensity and higher-energy beams emerging from Linac 4, the Proton Synchrotron Booster (PSB), which is the second accelerator of the LHC injector chain, will be completely overhauled during that same period. At the beginning of June, the first radio-frequency cavity of the new PSB acceleration system was completed, with a further 27 under assembly. The new cavities are based on a composite magnetic material called FINEMET developed by Hitachi Metals, which allows them to operate with a large bandwidth and means that a single cavity can cover all necessary frequency bands. The PSB cavity project was launched in 2012 in collaboration with KEK in Japan, and involved intensive testing at CERN. KEK contributed a substantial fraction of the FINEMET cores and shared its experience with similar technology.

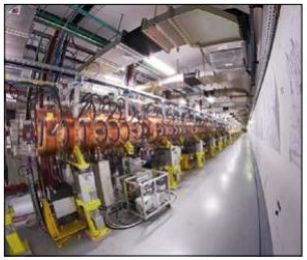


Image credits: M Brice

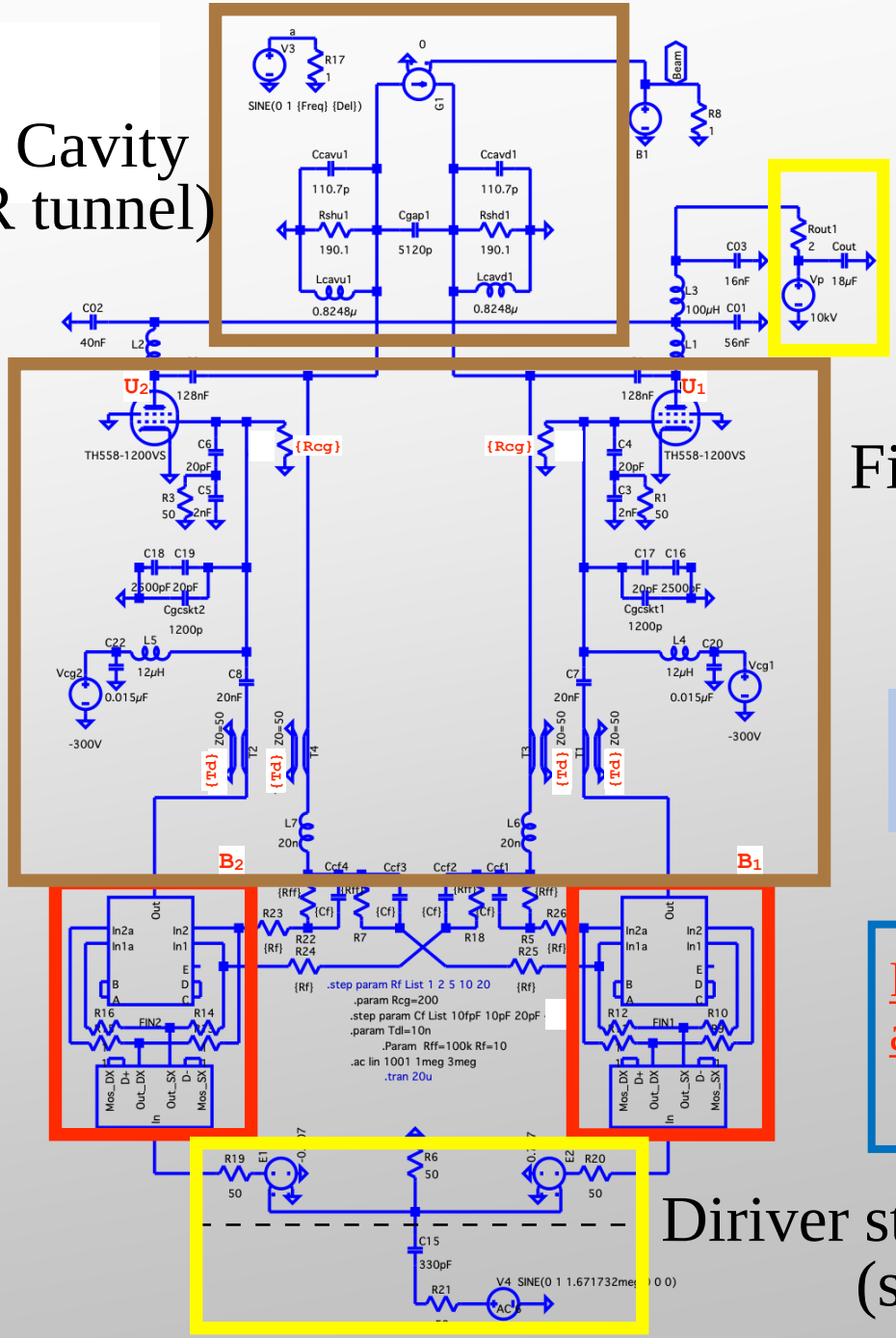
(Left) A view of the PI-Mode Structure (PIMS) cavities, which will accelerate the Linac 4 beam from 100 to 160 MeV. (Right) Mauro Paoluzzi, project leader for the PSB RF overhaul, with one of the FINEMET cavities that will allow more intense beams.

CERN Neutrino Platform

SSAs

Cavities

RF Cavity
(MR tunnel)



Anode power supply
(service building)

Final stage amplifier
(MR tunnel)

Test the rad-hard CERN SSA in the J-PARC MR tunnel

Rad-Hard Solid-State Amplifier applied in a fast feedback amplifier
(MR tunnel)

Diriver stage amplifier w/ LLRF
(service building)

Table 2 - MR RF System future plan (Revised in Feb. 2018)

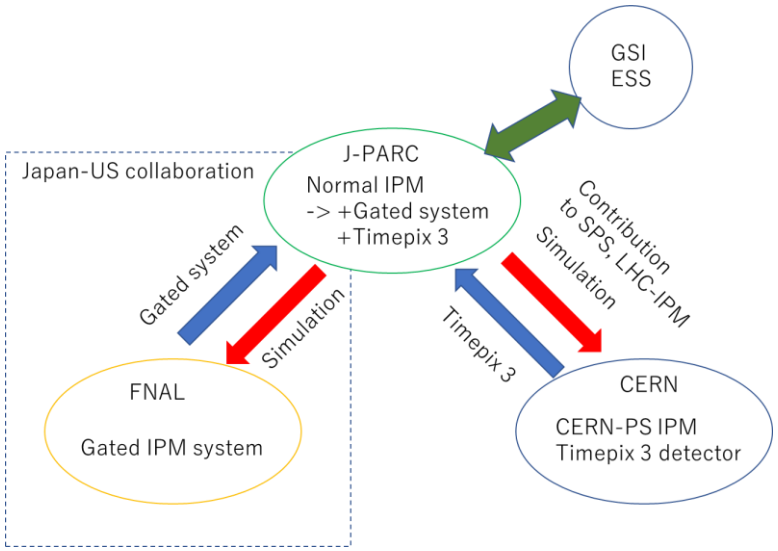
	2019	2020	2021	2022	2025	2026
Events	MR 2.48-sec operation	MR 2.48-sec operation	long shutdown	MR 1.32-sec operation	MR 1.32-sec operation	MR 1.16-sec operation
beam power (kW)	500 kW	500 kW	-	>700 kW	>900 kW	>1100 kW
FT3L 4GAP Cavities	***7***	***7***	***7***	9	9	***11***
additional 4GAP Cavity	-	-	-	*2*		
2nd harmonic cavity	***2***	***2***	*2*	***2***	***2***	***2***
Accelerating voltage	300-390 kV	300-390 kV	300-390 kV	510 kV	510 kV	600 kV
(2nd Harmonic)	110 kV	110 kV	110 kV	120 kV	120 kV	120 kV
LLRF(new)		*development*	*Installation*			
fast feedback amplifier (acc.system)		*2* (prototype)	*4*	*8*	*8*	
fast beedback amplifier (2nd Harmonic)			*4*			

Beam monitor collaboration

- J-PARC: K. Satou, A. Kobayashi, T. Toyama
- CERN: R. Jones, J. Storey

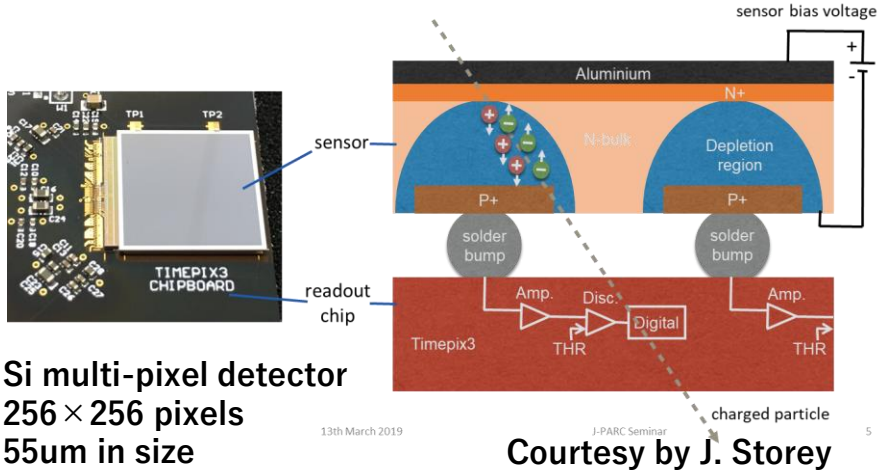
Ongoing collaboration

- **Ionization Profile Monitor (IPM)=BGI**



Many concerns of IPM
- IPM system for high intensity beams
  - Es ~ a few MV/m
  - Accuracy limitation?
- Simulation code development (J-PARC)
- Timepix3 detector system (CERN)
- HV Gated system (FNAL)

- **Fast Beam loss monitor (Timepix3 base)**



Si multi-pixel detector
256×256 pixels
55um in size

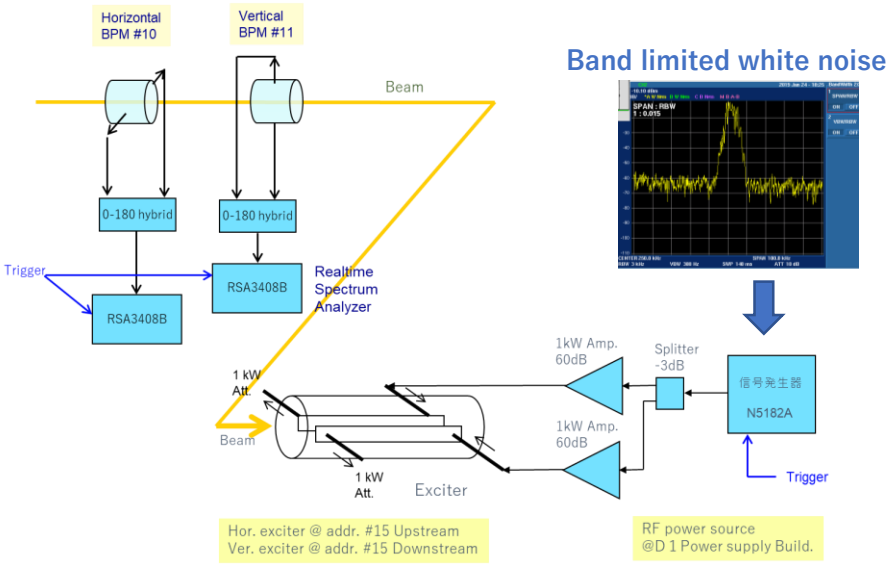
Courtesy by J. Storey

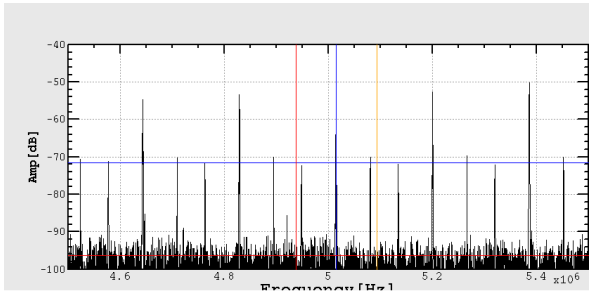
Multipixel 55um size Si sensor, on-chip digital sampling, rad-hard system

1)Collision angle determination -> Loss point
  /Particle tracking in Si
  /Point to point coincidence between two Timepix3 detectors
2)Energy deposit determination -> Particle ID
  /Fast Neutron detection using converter
  /Charged K, π, μ: as a MID particle

Upgrade plan: Tune measurement by BBQ

J-PARC Tune Meter system





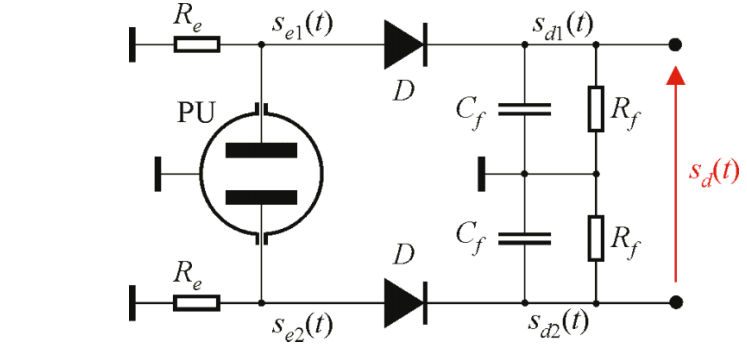
BPM Δ signal -> Spectrum analyzer
Need kick to excite beam oscillation -> Beam loss

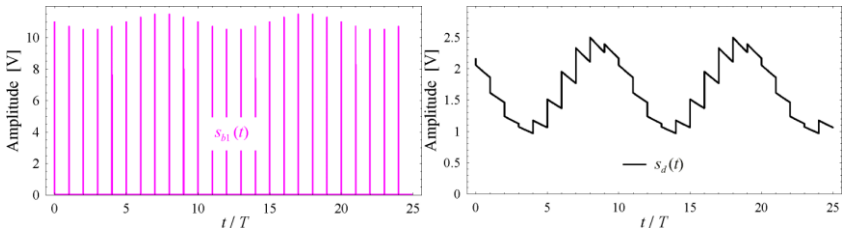
CERN BBQ system

Pick up signal is an Amplitude Modulation signal

$$x(t) \propto x_0 \sin(Q\omega_0 t)\delta(t - nT_0)$$

Non-integer part of Tune　　Bunch revolution





From presentation file by M. Gasior, R. Jones, DIPAC2005

Tune monitoring during stable beam operation

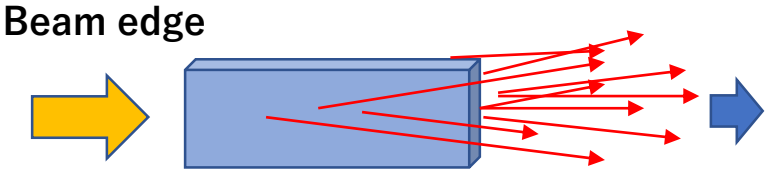
Concerns

- Design of diode detection system
- Pickup signal <200Vpp
- Usage in the tunnel -> Tolerance for radiation

Possible collaborations (from the discussions at the workshop)

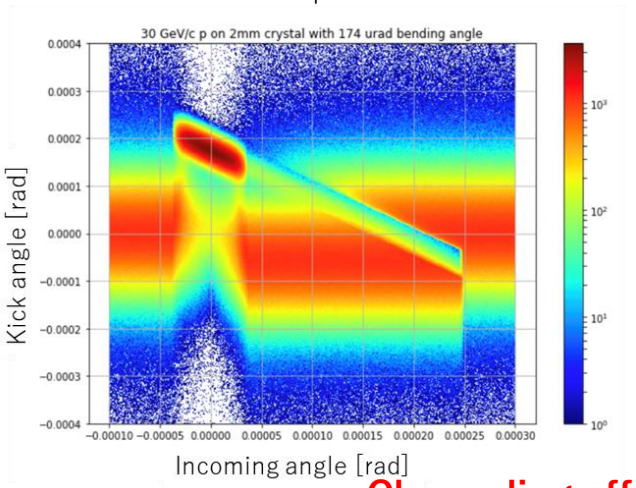
- On going project: IPM (BGI), Fast BLM
  - IPM: One of the promising tools to measure high intensity proton beams
  - Timepix3 BLM has many potential: Loss point and particle ID: Would like to introduce, and test at J-PARC
- Interesting collaborations
  - BPM: Learn more about CERN system: Firstly, special mini-workshop would be better
  - DCCT
  - BBQ: Would like to design and introduce the similar system of CERN BBQ system to realize real time tune measurements
    - Learn the CERN system to design J-PARC MR BBQ
    - Need advices and supports
  - Flying wire monitor (Wire-scanner): Practically 2nd or 3rd priority, however・・・・・

Slow-beam loss reduction by Diffuser/Crystal: SX



Multiple scattering gives a scattering angle distribution to a particle

Crystal effect scaled from 350 GeV to 30 GeV
L. Esposito



Channeling effect

- J-PARC: M. Tomizawa, R. Muto
- CERN Acc. beam transfer group: B. Goddard, M. Fraser, F. Velotti

Beam loss rec … -PARC SX based on CER

◎**Tracking simul** … (diffuser, crystal) and **Analy**

Preliminary

- Location0 …
- Silicon cry … drastica … 250μm t …
- Diffuser al … W/Re: …

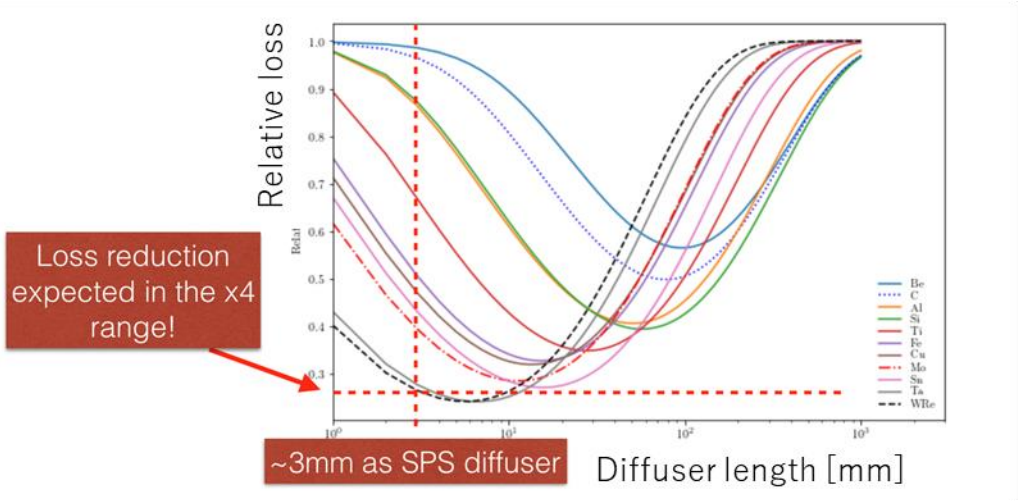
◎A further **new i** … e than the single diffuser +E …

Crystal-…

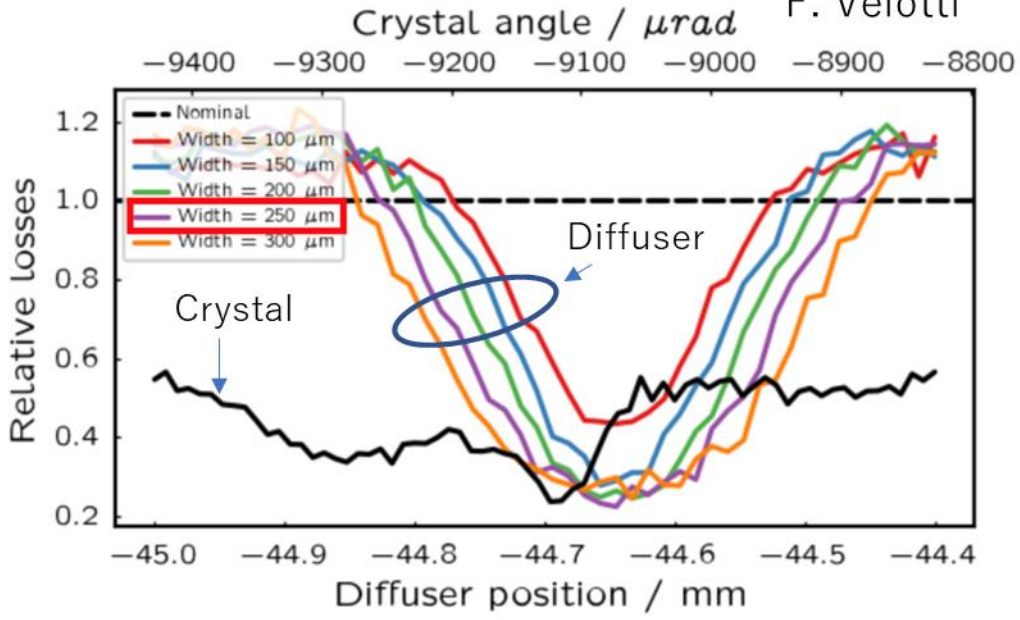
◎**More realistic** …

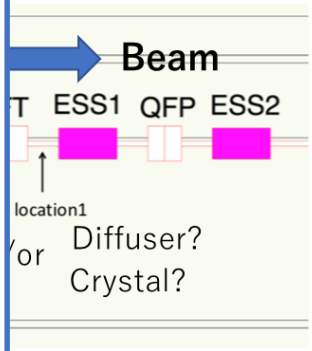
◎J-PARC has sta … **funding**.

Diffuser (analytical) by B. Goddard



F. Velotti





Summary: Progresses and new Proposals

- New abort beam dump
  - Design works for the new abort beam dump
    - Design progress, and design items to be concerned
  - At each stage of design works, need discussions and advices from CERN
- RF
  - Issues on the fast feedback RF system have been discussed
  - Performance test of the CERN's Rad-hard Solid State Amplifier (SSA) is planned at J-PARC ***(New Proposal)***
- Beam Monitor
  - IPM collaborations: J-PARC MR, CERN PS, SPS, and LHC
  - New Beam Loss Monitor system based on the Timepix3
    - Performance test at J-PARC MR is planned ***(New Proposal)***
  - Base Band Q (BBQ) measurement system for J-PARC ***(New Proposal)***
    - Design works supported by CERN
  - Next generation Beam Position Monitor system ***(New Proposal)***
    - Start discussion
- Slow extraction (SX)
  - Diffuser and Crystal system for slow extraction have been discussed
  - Tracking simulations by CERN and J-PARC
    - Beam loss reduced to ¼
  - Hardware design of the Diffuser and(or) Crystal systems for J-PARC