

Beam Injection Operation for Particle Physics and Photon Science Experiments with Pulse-to-Pulse Beam Modulation



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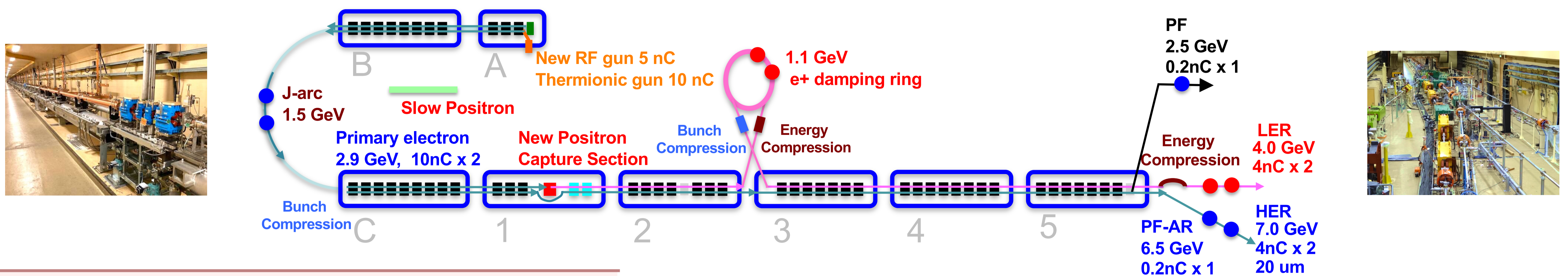
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The electron and positron accelerator complex at KEK offers unique experimental opportunities in the fields of elementary particle physics with SuperKEKB collider and photon science with two light sources. In order to maximize the experimental performances at those facilities the injector linac employs pulse-to-pulse modulation at 50 Hz, injecting beams with diverse properties. The event-based control system effectively manages different beam configurations. This injection scheme was initially designed 15 years ago and has been in full

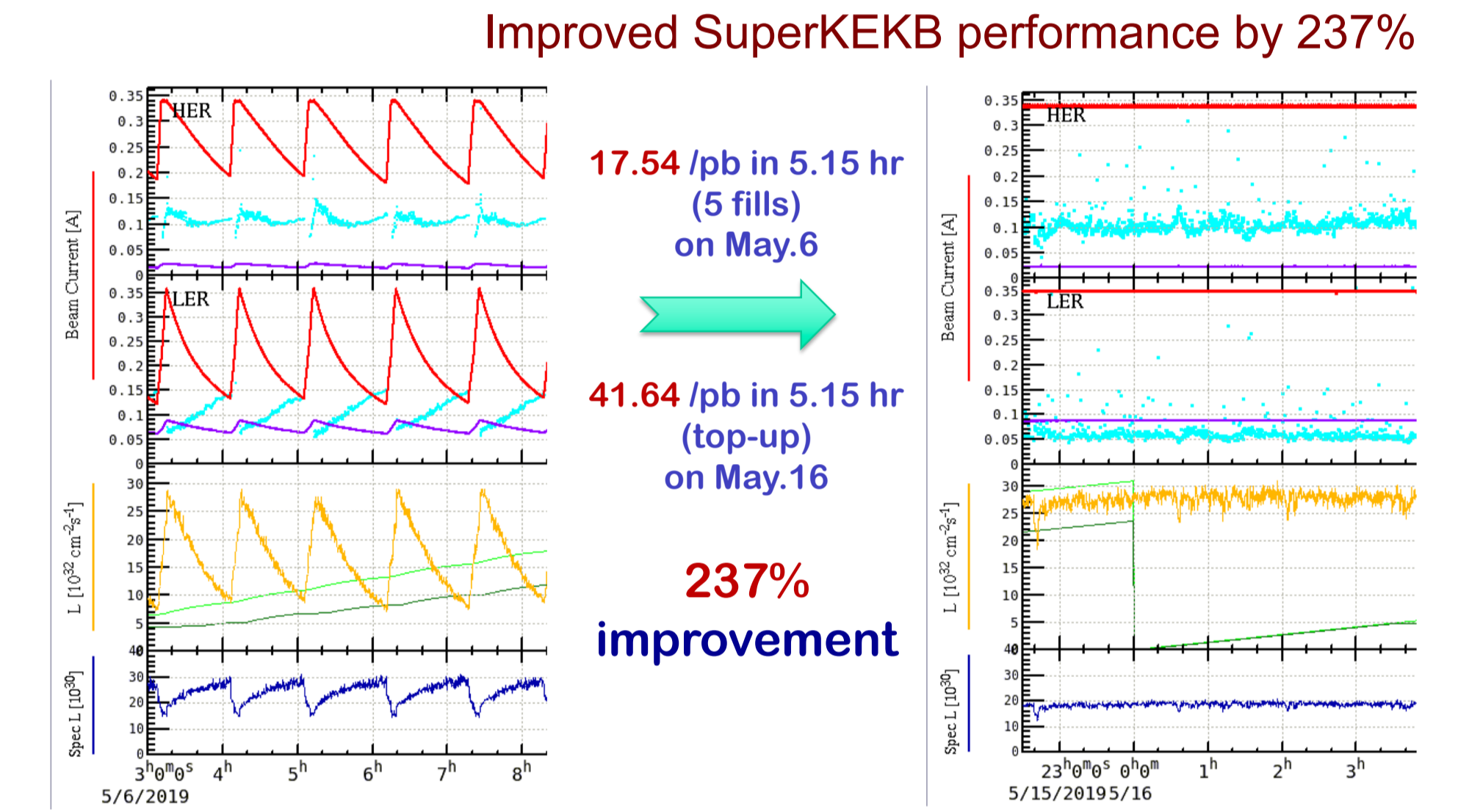
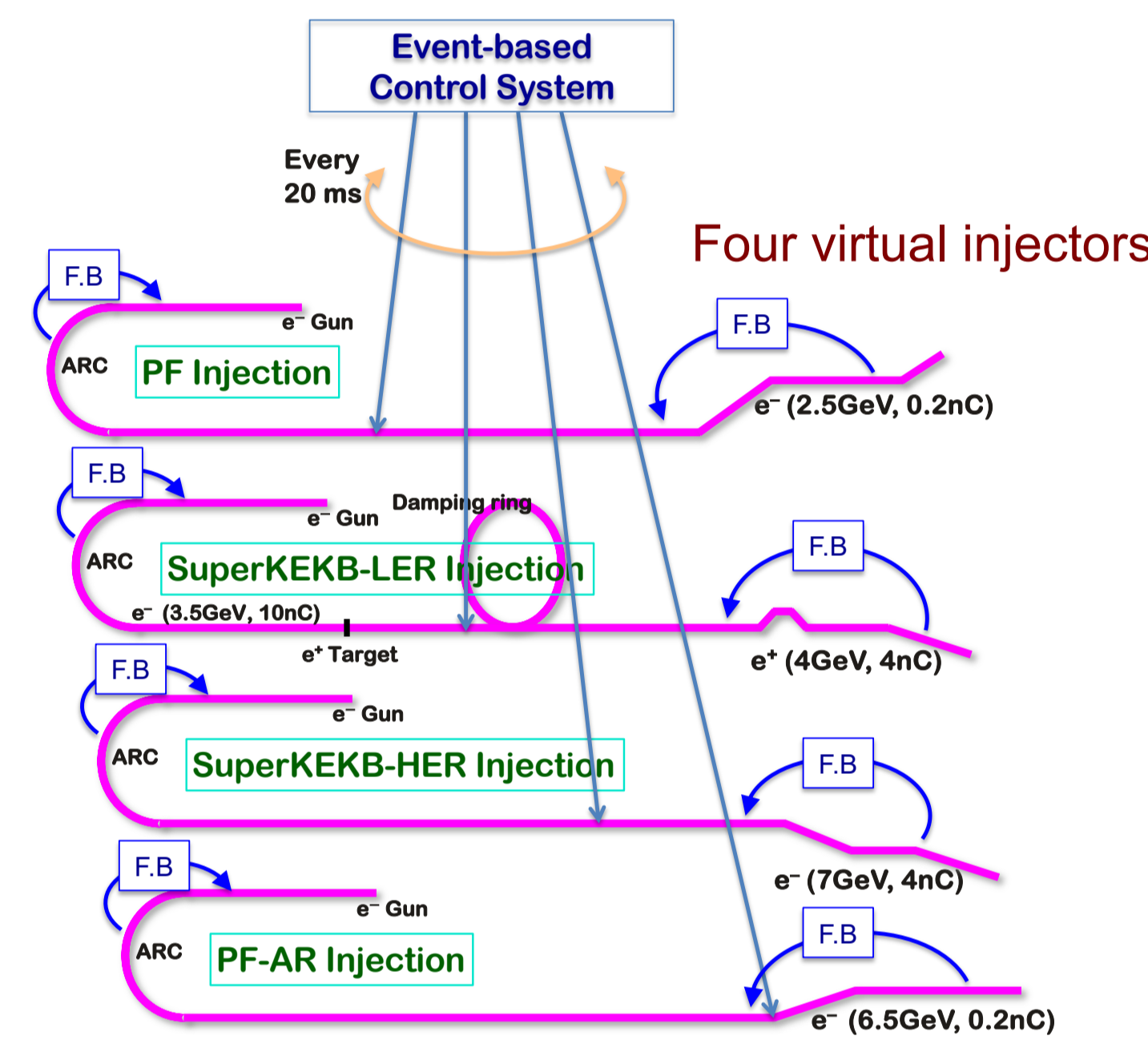
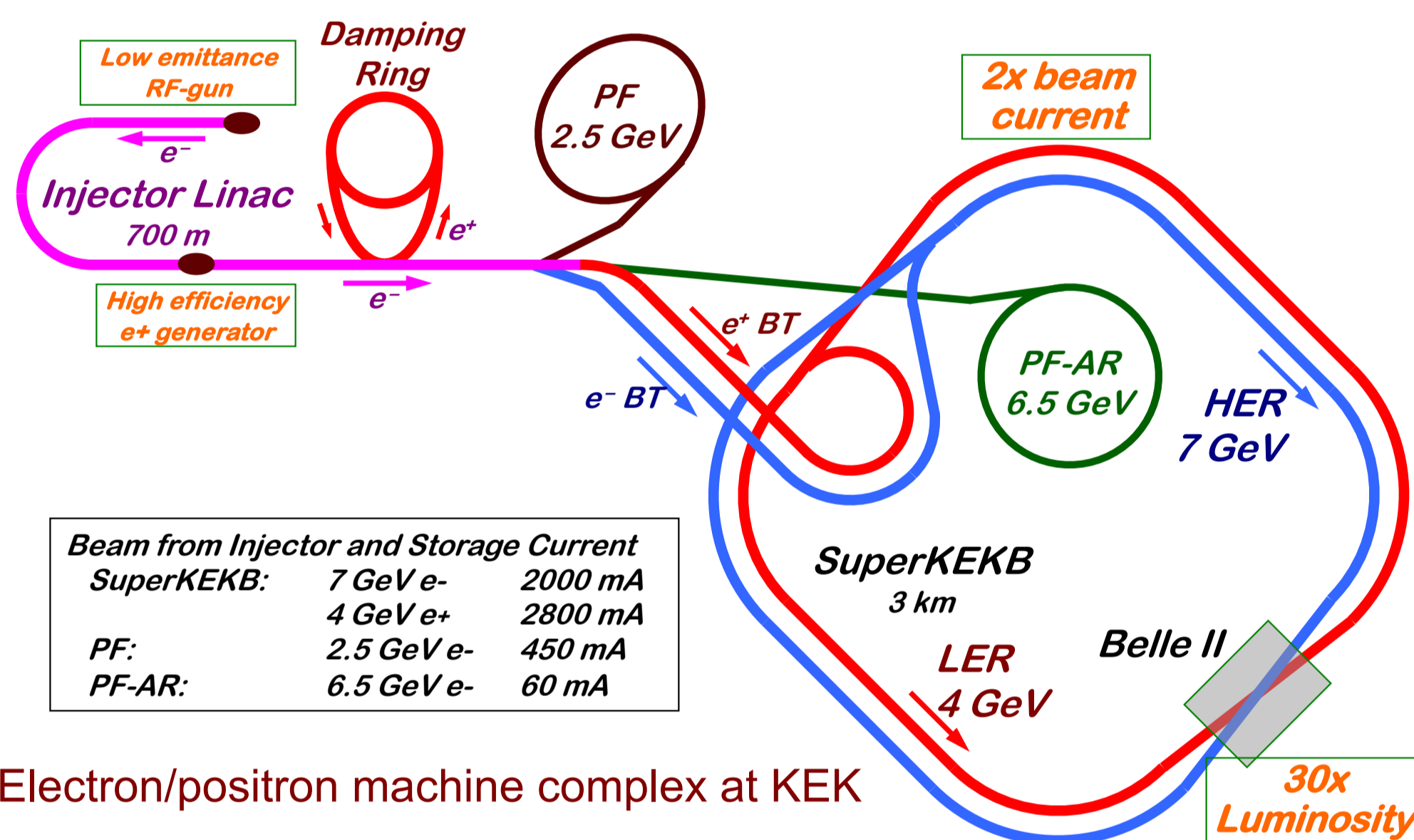
operation since 2019. Over the years, a number of enhancements have been implemented. As the event-based controls are tightly coupled with microwave systems, machine protection systems and so on, their modifications require meticulous planning. However, the diverse requirements from particle physics and photon science, stemming from the distinct nature of those experiments, often necessitate patient negotiation to meet the demands of both fields. This presentation discusses those operational aspects of the multidisciplinary facility.

KEK e⁻ / e⁺ injector LINAC delivers multi-disciplinary beam injections for 4 + 1 storage rings of light sources and a particle physics collider even with higher beam charge and lower beam emittance

Injector LINAC Configuration



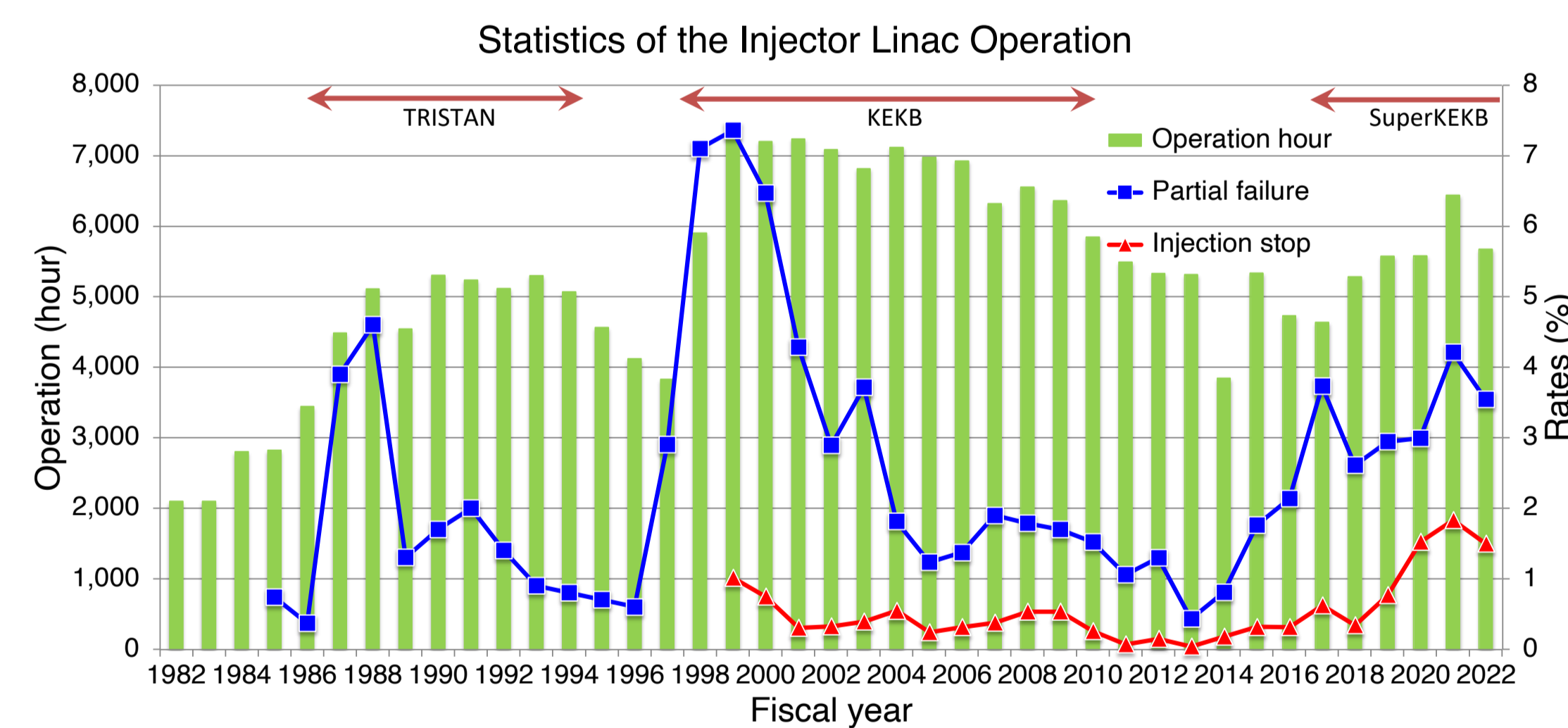
Simultaneous Top-up Injections into 4 + 1 Rings



Historical Linac Beam Deliveries

Project	Injection Energy	Exp. Energy	1970	1980	1990	2000	2010	2020
Photon Factory	2.5 GeV	2.5 GeV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation
TRISTAN	2.5 GeV	32 GeV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation
Slow Positron	2.5 GeV - 55 MeV	0.1 - 35 keV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation
KEKB	8 / 3.5 GeV	8 / 3.5 GeV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation
PF-AR	2.5 GeV - 6.5 GeV	5 - 6.5 GeV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation
SuperKEKB	7 / 4 GeV	7 / 4 GeV	Construct.	Construct.	Injection Operation	Injection Operation	Injection Operation	Injection Operation

Beam Injection Statistics



Dual Disciplinary Beam Injection

PF / PF-AR photon science

- ◆ Short-term in many user groups
- ◆ Stability intensive (Hates failures)
- ◆ Meticulous scheduled maintenance
- ◆ Invests on maintenance
- ◆ Formal common objective between users
- ◆ Fixed procedures

SuperKEKB particle physics

- ◆ Long-term and fixed single user group
- ◆ Performance intensive (Integral performance during a year)
- ◆ Minimum preventive maintenance
- ◆ Invests on improvements
- ◆ May share common goal with the user
- ◆ Everyday is new

◆ Injector linac arbitrates between downstream accelerators with incompatible disciplines for long-term plans, yearly maintenance and improvements, and daily beam deliveries



Required Beam Performance

Stage	KEKB (final)	Phase-I (achieved)	Phase-II (achieved)	Phase-III (interim)	Phase-III (final)	
Beam Energy	3.5 GeV	8.0 GeV	4.0 GeV	7.0 GeV	4.0 GeV	7.0 GeV
Stored current	1.6 A	1.1 A	1.0 A	1.0 A	1.8 A	1.3 A
Life time (min.)	150	200	100	100	6	6
Bunch charge (nC)	1	1	0.5	1	2	2
Norm. Emittance (μm)	1400	310	1000	130	200/40	150/30
Energy spread	0.13%	0.13%	0.50%	0.50%	0.16%	0.10%
Bunch / Pulse	2	2	2	2	2	2
Repetition rate	50 Hz	25 Hz	25 Hz	25 Hz	50 Hz	50 Hz
Simultaneous top-up injection (PPM)	3 rings (LER, HER, PF)	No top-up	Partially	4+1 rings (LER, HER, DR, PF, PF-AR)	4+1 rings (LER, HER, DR, PF, PF-AR)	

Summary

- ◆ KEK injector LINAC continues simultaneous top-up injections to support the both photon science and particle physics experiments.
- ◆ It often carries administrative and operational negotiations to a successful conclusion to enable short-term and long-term optimizations and to enhance performances for the both disciplines.