Operation Model, Availability and Performance

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FCC-ee physics operation model

working point	nominal luminosity/IP [10^{34} cm^{-2}s^{-1}]	total luminosity (2 IPs)/ yr half luminosity in first two years (Z) and first year (ttbar) to account for initial operation	physics goal	run time [years]
***Z* first 2 years**	100	**26 ab^{-1}/year**	**150 ab^{-1}**	**4**
***Z* later**	200	**48 ab^{-1}/year**		
W	25	**6 ab^{-1}/year**	**10 ab^{-1}**	**1 - 2**
H	7.0	**1.7 ab^{-1}/year**	**5 ab^{-1}**	**3**
machine modification for RF installation & rearrangement: 1 year				
top 1st year (350 GeV)	0.8	**0.2 ab^{-1}/year**	**0.2 ab^{-1}**	**1**
top later (365 GeV)	1.4	**0.34 ab^{-1}/year**	**1.5 ab^{-1}**	**4**

total program duration: 14 – 15 years - *including machine modifications*

phase 1 (*Z, W, H*): 8 – 9 years, phase 2 (top): 6 years

luminosity estimate based on

$$\boxed{L_{\mathrm{int}}/\mathrm{year} \approx T\;E\;L_{\mathrm{nominal}}}$$

efficiency

number of days scheduled for physics per year

nominal (design) luminosity

FCC-ee assumptions:
T=185 days,
E= 75% (with top-up injection)

T

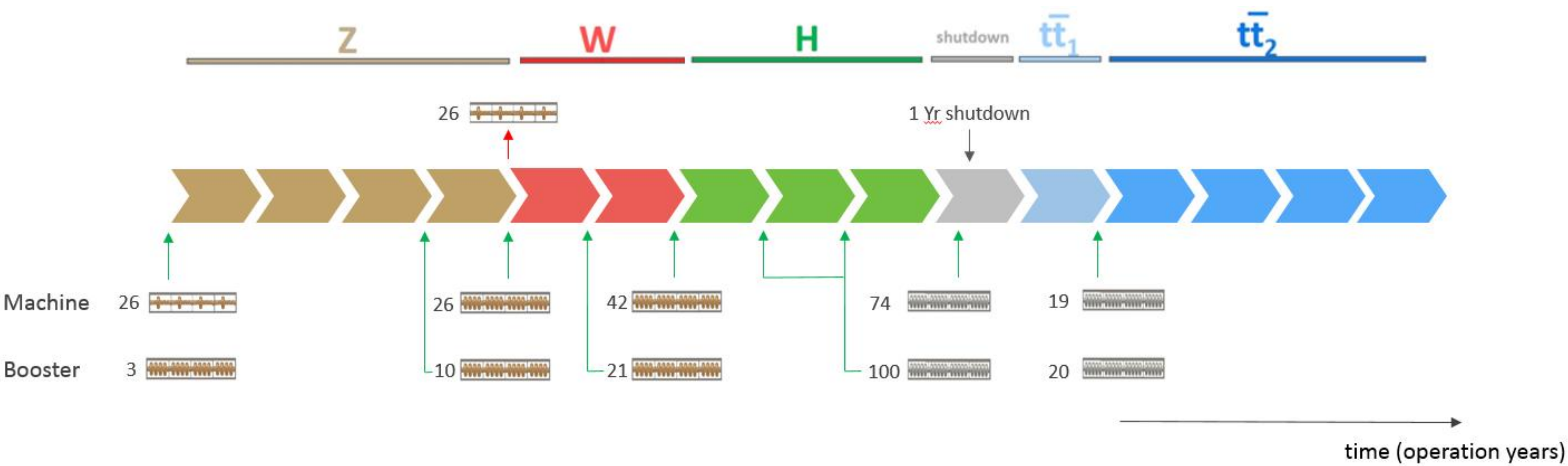
days scheduled for physics per year

T =

365 days
– **17 weeks (119 days) winter shutdown**
– 30 days commissioning
– **20 days for MDs**
– 11 days for technical stops

= 185 days

length of winter shutdown?
- dominated by RF installation



FCC-ee operation time line, with installation of cryomodules

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length of winter shutdown

considering a single cryomodule transport per working day, the minimum total length of the winter shutdown is estimated as

$$n_{\text{working-days}} = n_{\text{cryomodule}} + 10 + 10 + 25$$

where
first 10 days: end of the installation,
second 10 days: cool down,
last 25 days: interlock tests and rf conditioning (5 weeks)

these numbers assume that pre-installation work and pre-cabling will be done in advance (i.e. during the previous shutdowns);
in addition a minimum of 12 weeks is recommended for the first three shutdowns

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minimum lengths of FCC-ee winter shutdowns; shutdown no. 1 refers to the first shutdown after one year running on the Z pole.

shutdown	no. cryomodules	length of shutdown
shutdown 1	–	12 weeks
shutdown 2	–	12 weeks
shutdown 3	10 CM	12 weeks
shutdown 4	26 CM	20 weeks
shutdown 5	21 CM	14 weeks
shutdown 6	42 CM	18 weeks
shutdown 7	30 CM	15 weeks
shutdown 8	30 CM	15 weeks
long shutdown	104 CM	1 year
shutdown 11	39 CM	17 weeks
shutdown 12	–	–
shutdown 13	–	–
shutdown 14	–	–

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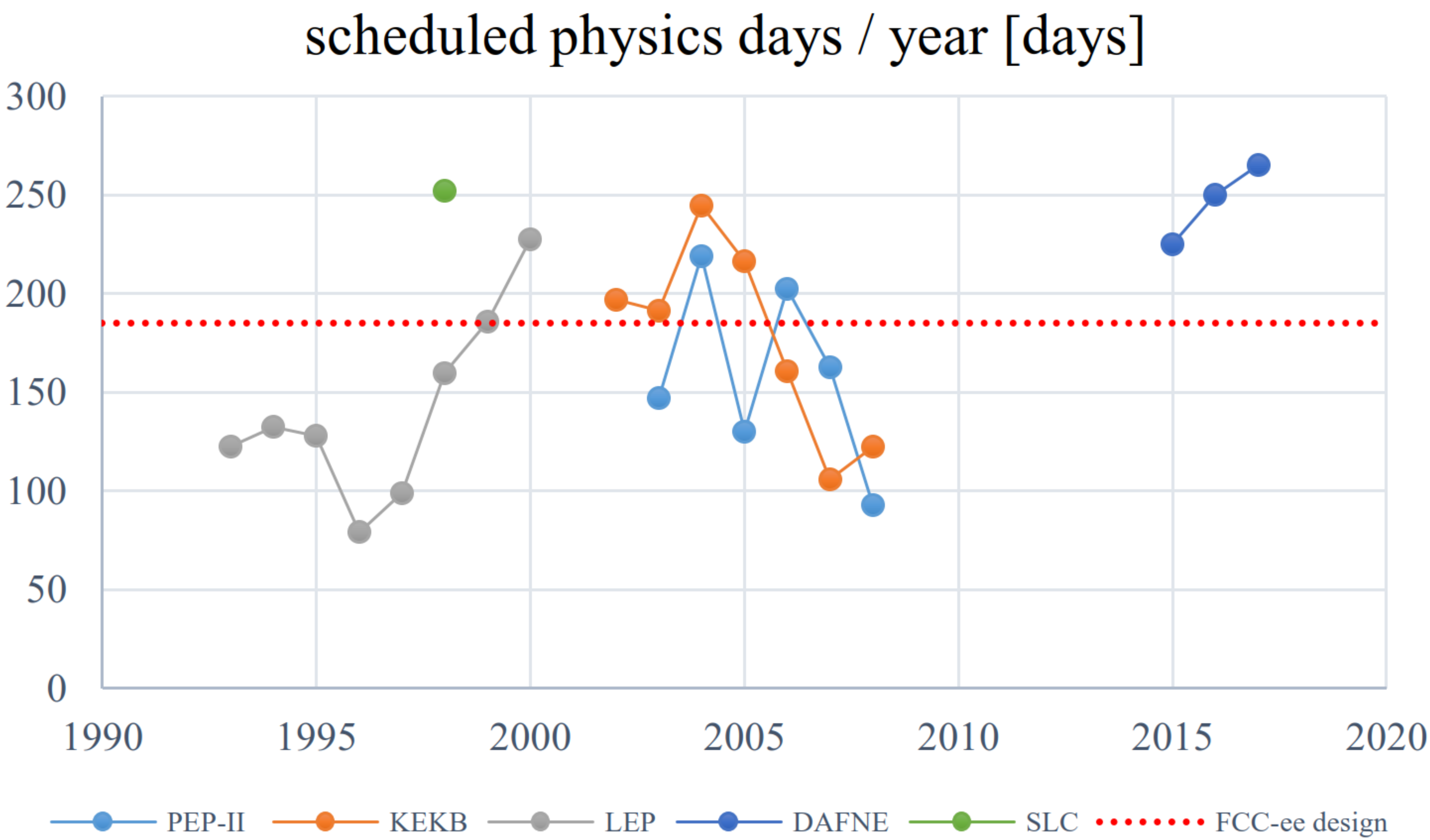
average value: 11.25 weeks (assumption is 17 weeks!)



days of the year dedicated to physics at various past & present e+e− colliders

the run lengths of these colliders *were often dictated by the availability of financial budget for operation*, and not by any technical or schedule constraints; this is true in particular for PEP-II and KEKB; in addition, *for PEP-II the 2005 run length was severely reduced by a SLAC lab-wide investigation*, review, and remediation of safety concerns, and re-validation of all systems and procedures

E

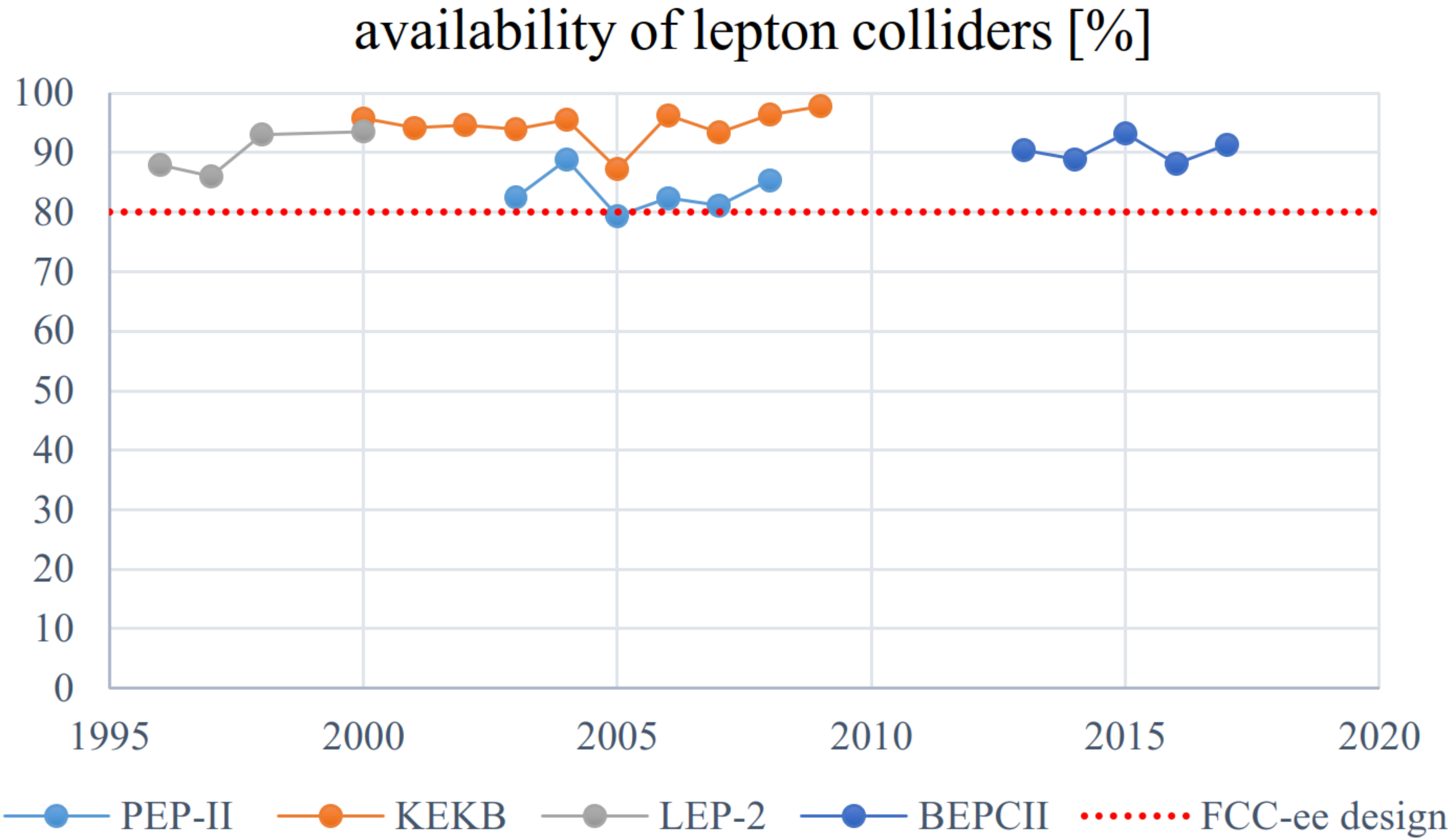
$E < A$ (machine availability)

FCC-ee assumption:

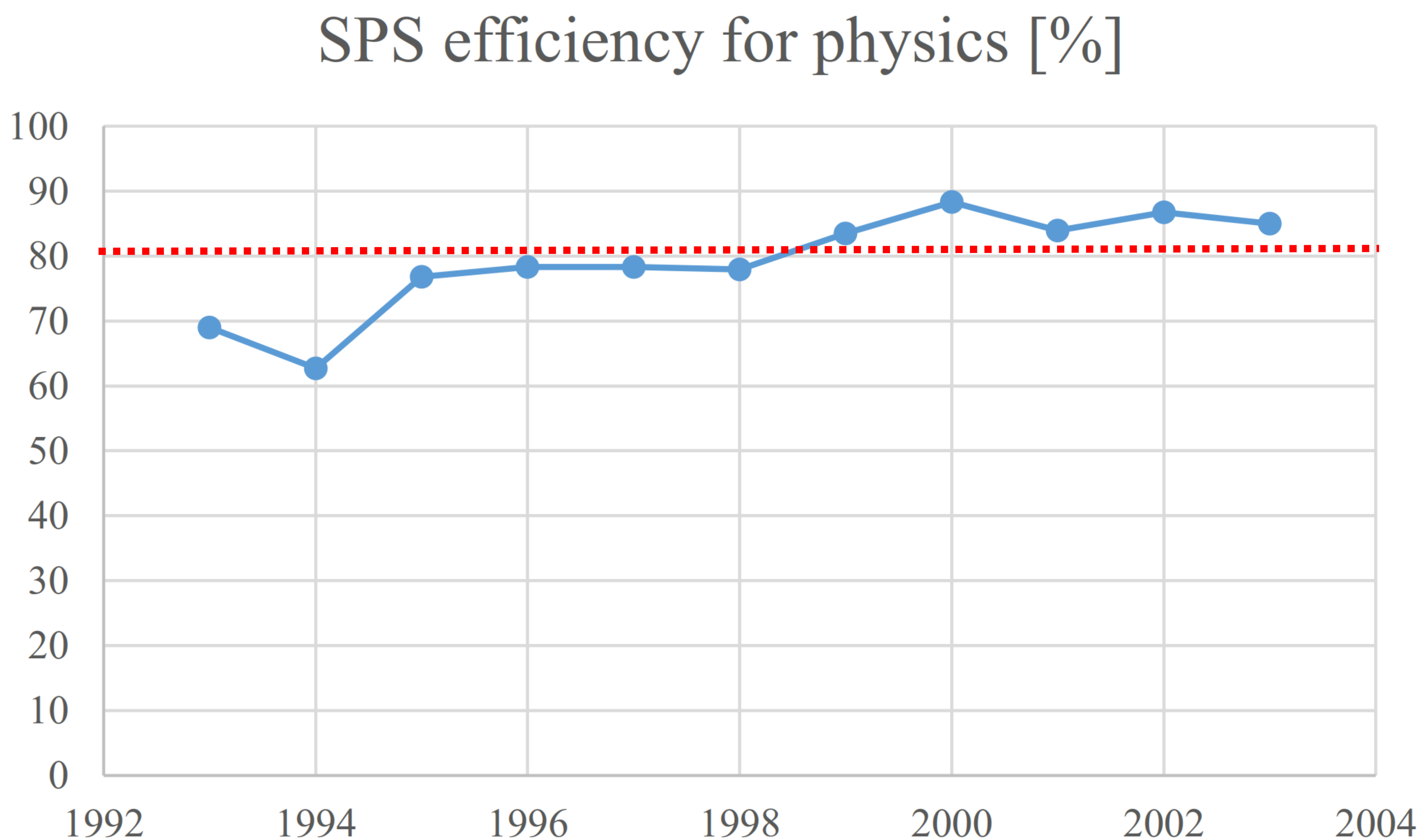
$A \geq 80\%$ to obtain $E \geq 80\% - 5\% \sim 75\%$

recovery from 3 failures/day ~5% at the Z [filling time: 18 min (Z), 2 min (H)]

A



availability of various past and present e^+e^- colliders

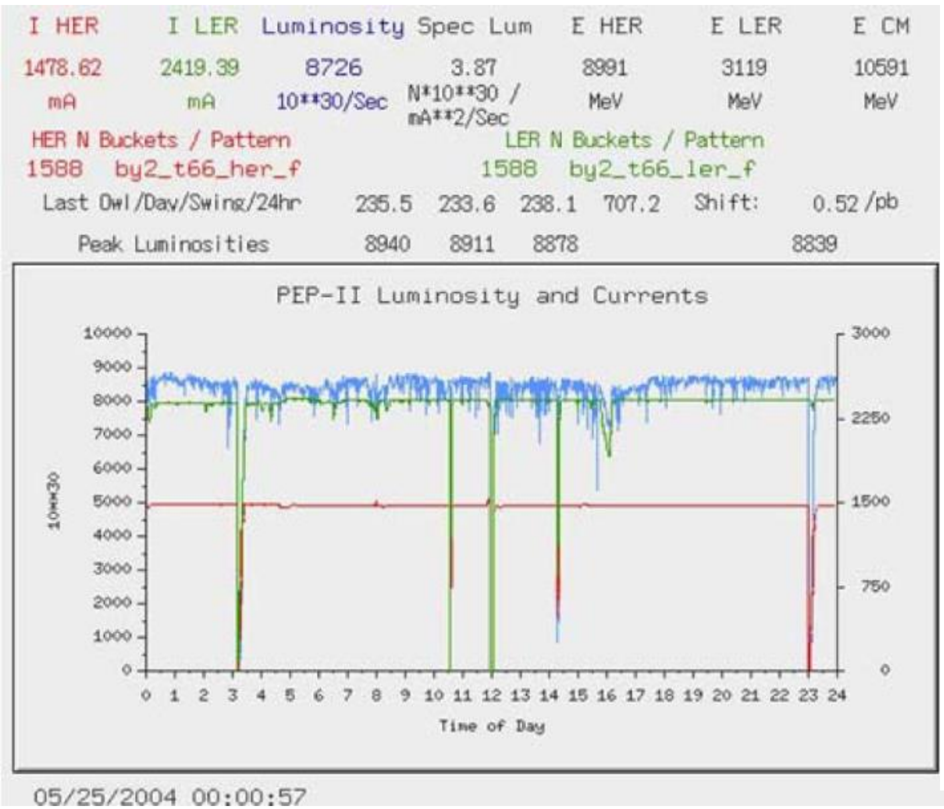


CERN SPS efficiency for physics, including the PS chain

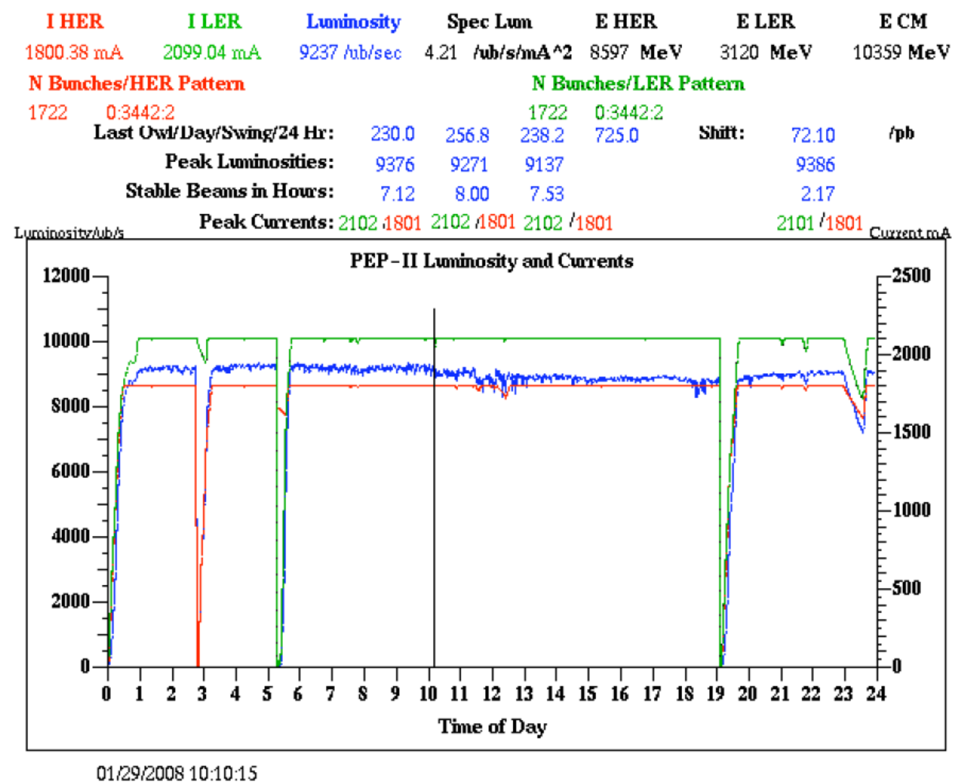
E (empirical)

Efficiency – PEP-II operation with on-energy top-up injection

2004



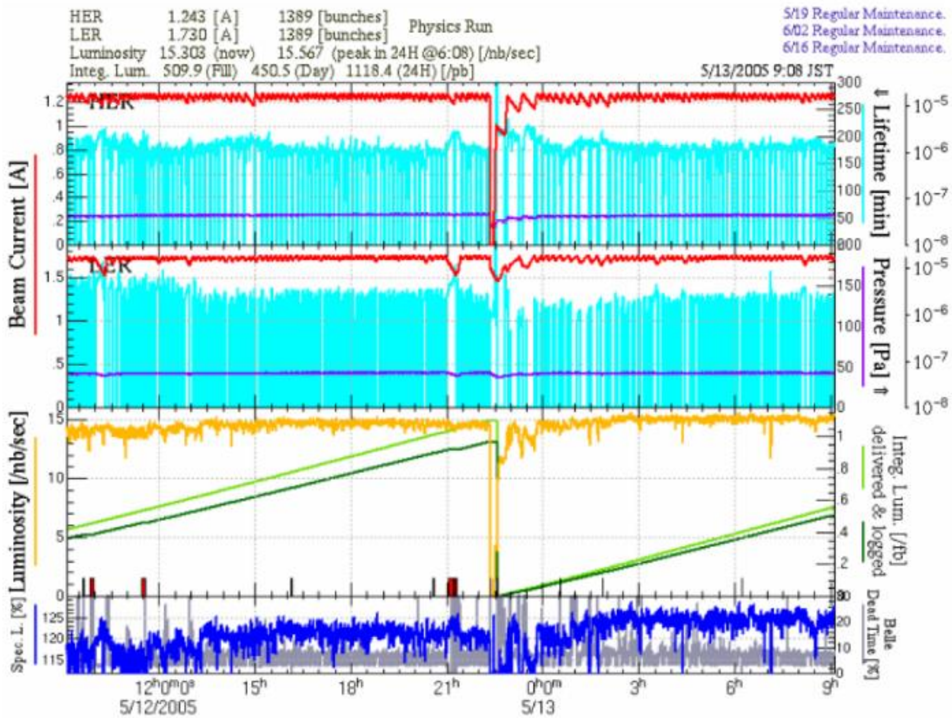
2008



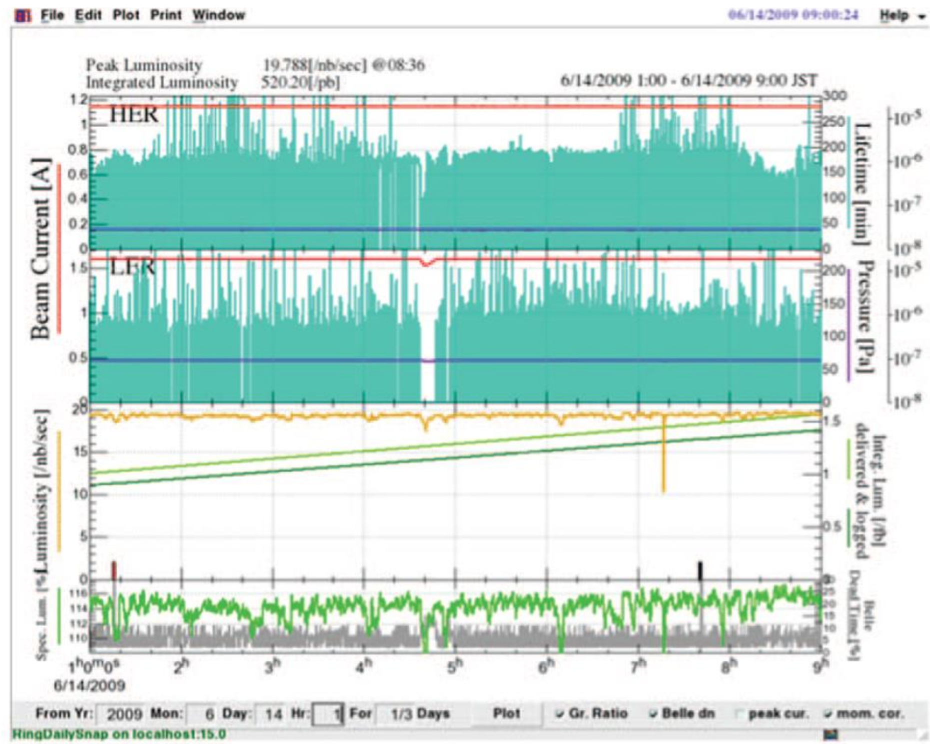
Example evolutions of PEP-II beam currents and luminosity. Stored beam current of HER (red curve), LER (green curve), and luminosity (blue curve) of PEP-II over 24 h.

Efficiency – KEKB operation with on-energy top-up injection

2005

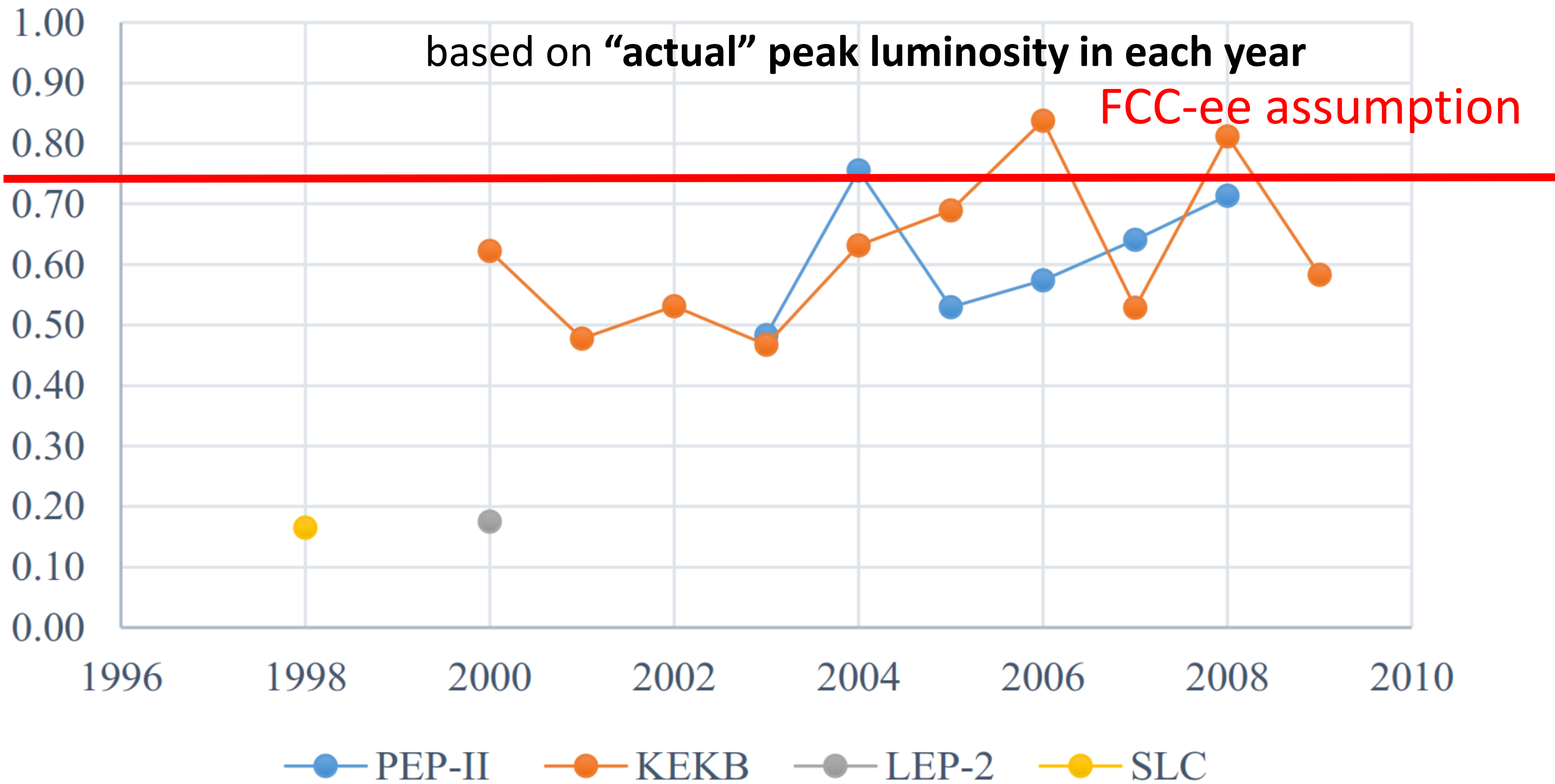


2009

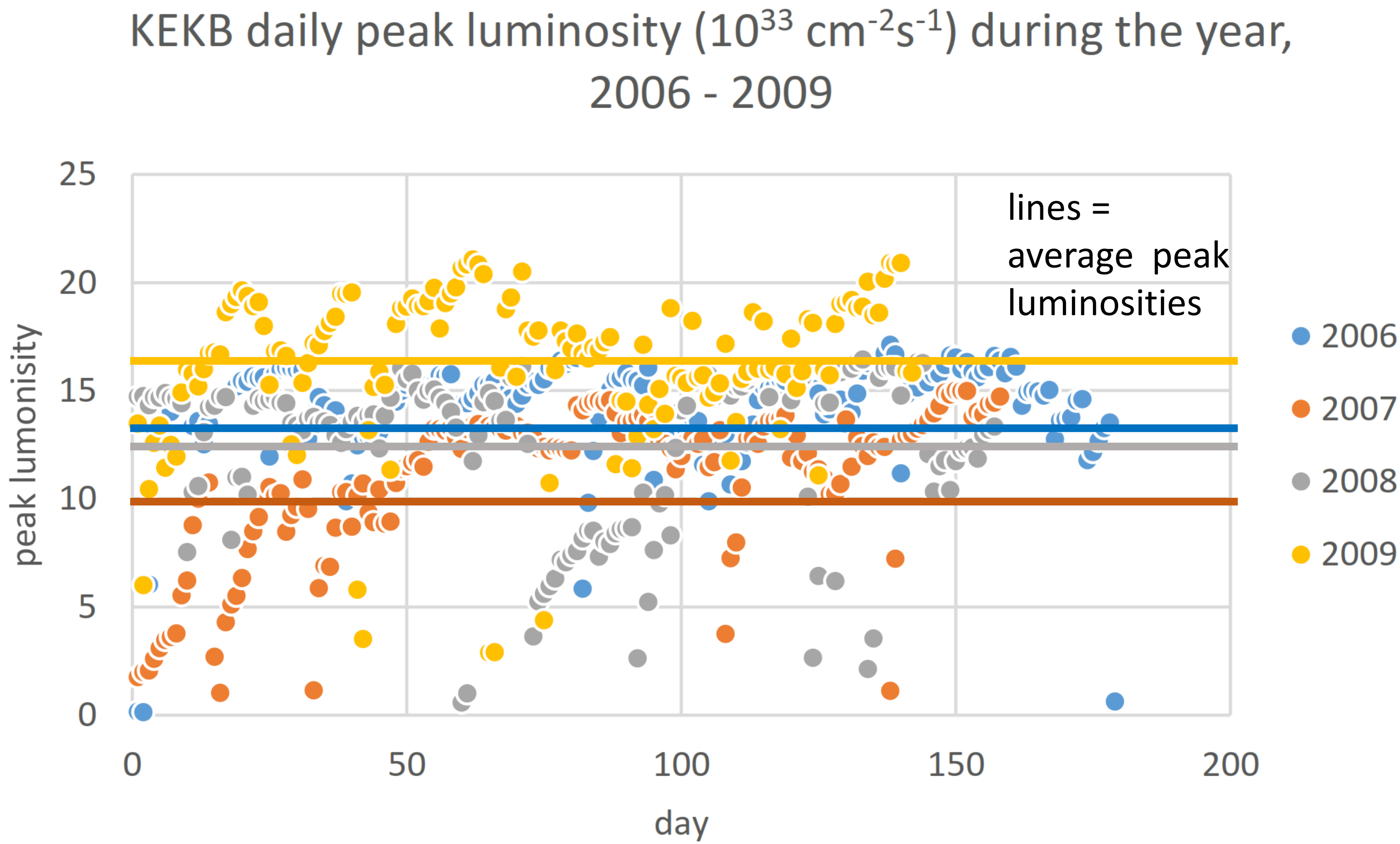


Example evolutions of KEKB beam currents and luminosity. Stored beam current of HER (red line in the top figure), LER (red line in the middle figure), and luminosity (yellow line in the bottom figure) of KEKB over 24 h.

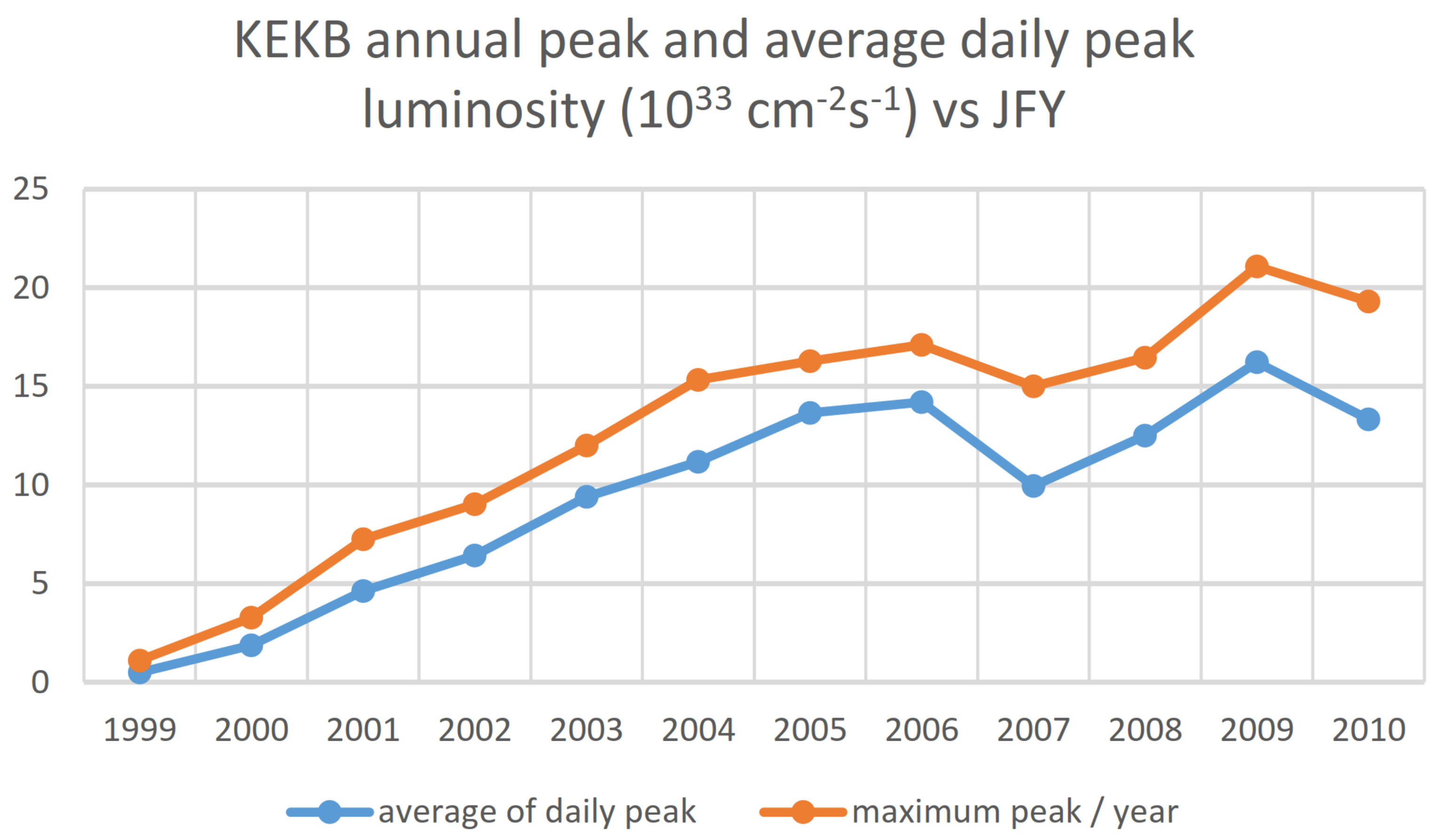
efficiency of lepton colliders – one definition



the question is which peak luminosity to take for each year -
peak in that year (LEP), peak reduced by ~15% (above SLC, PEP-II above), average peak over the year after removing values <10% (KEKB), design value (easiest, well defined – FCC-ee)

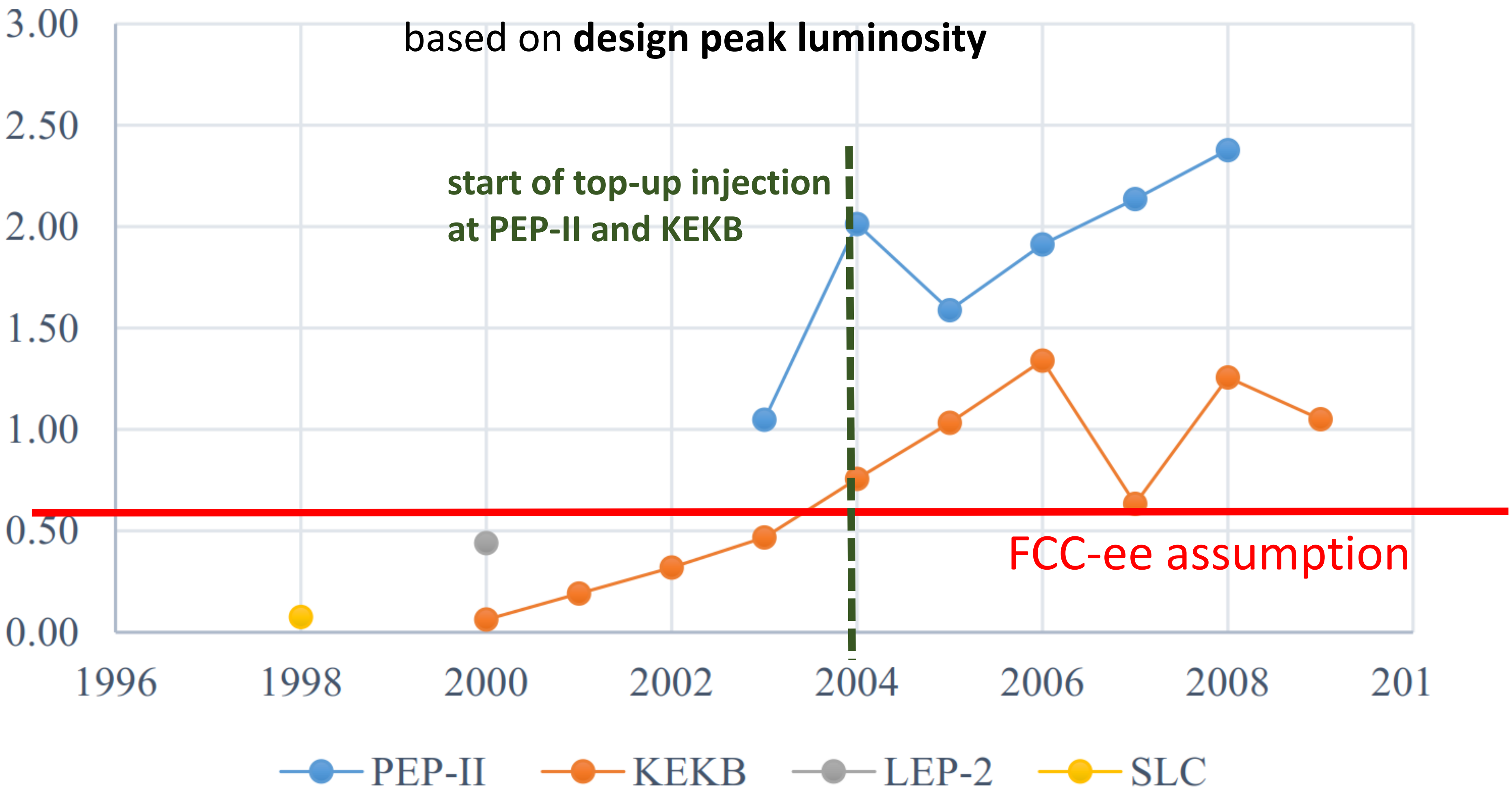


daily peak luminosity of KEKB as a function of day in the physics run, starting on 1 April, during four consecutive Japanese fiscal years



maximum peak luminosity and average daily peak luminosity of KEKB as a function of Japanese fiscal year

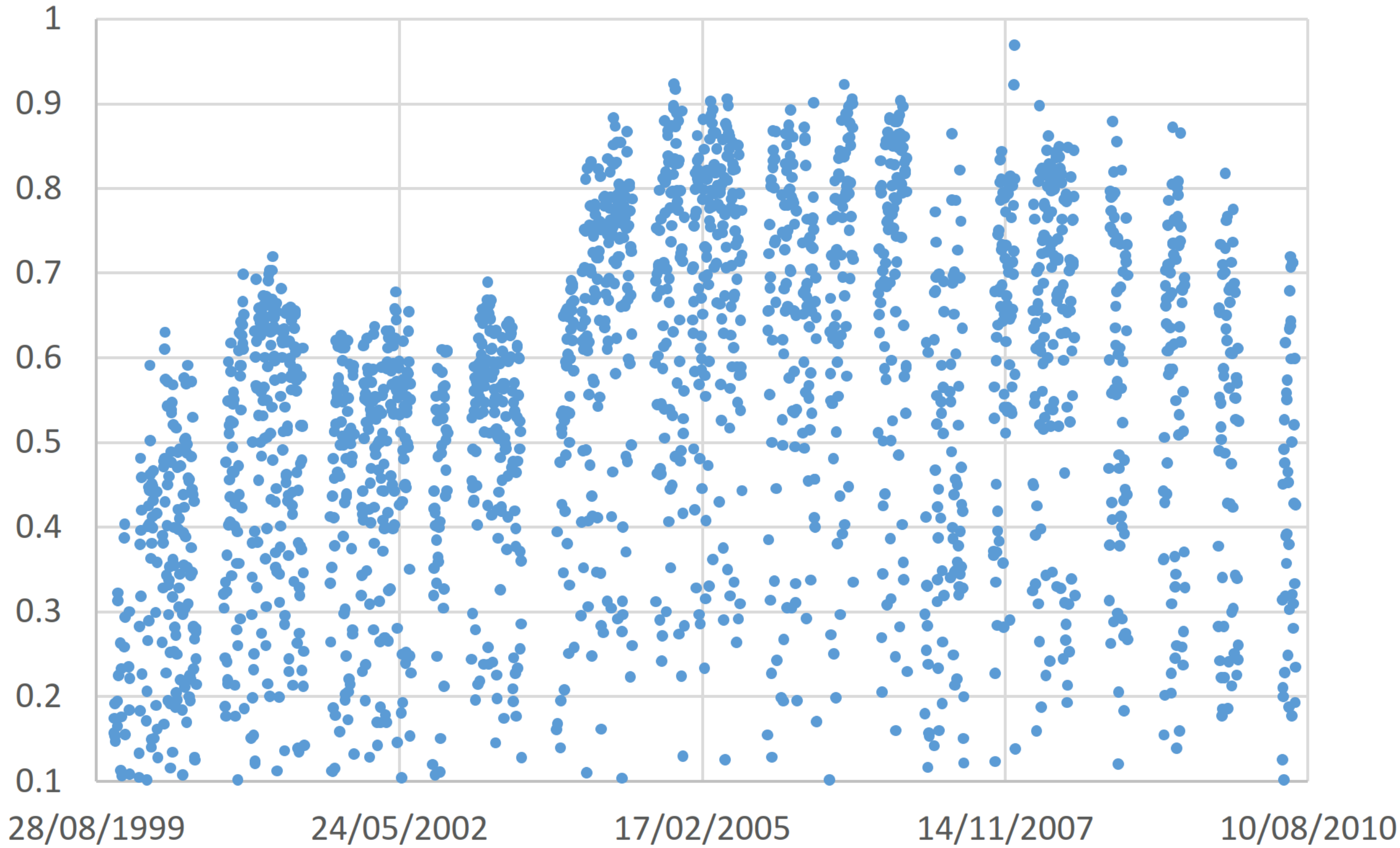
efficiency of lepton colliders – a second definition



more than 100% !?!

KEKB day-by-day efficiency

based on **day-by-day peak and integrated luminosity**



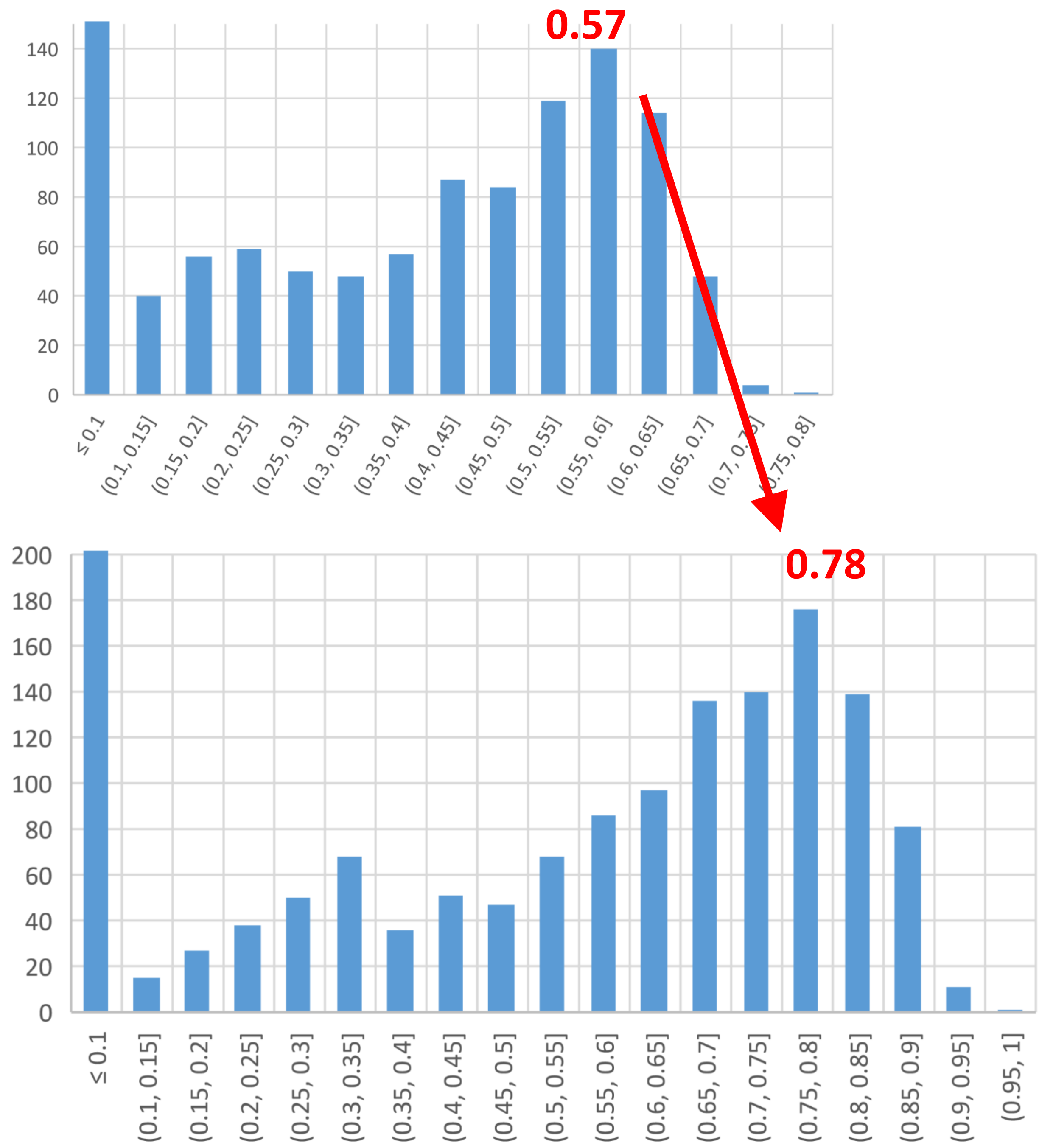
daily efficiency

KEKB 1999-2003

without top up

KEKB 2003-2010

with top up



beyond the baseline?

Exceeding the FCC-ee Baseline Performance

LEP, PEP-II, and KEKB exceed the design performance ; the FCC-ee could do so too:

- **baseline luminosity is 10–15% lower than simulated**
- other **beam parameters**, more challenging for RF, yield **higher luminosity**
- **vertical emittance could be pushed down further**; far from the intrinsic limits
- **tolerated minimum beam lifetime is significantly longer than what could be supported by the top-up injector complex (2-12 min.)**
- assumed **two years or one year, respectively, in phase 1 and phase 2 at half the design luminosity could be too pes**simistic

a few conclusions

assumed annual physics run time of 185 days,
hardware availability of at least 80%,
corresponding physics efficiency of 75%, and
projected annual luminosities of FCC-ee
look solid, in view of the experience at several
circular lepton colliders over the past 30 years

surpassing FCC-ee baseline values for both peak
and integrated luminosity appears a possibility