2nd RULε Topical Workshop on Injection and Injection Systems, PSI, Apr 1-3, 2019

Future Machines #2

Closeout

Michael Böge (PSI), Simon C. Leemann (ALS)

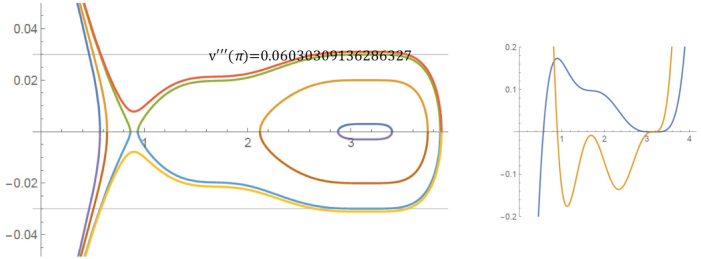
HEPS Injection (Gang Xu)

RF gymnastics for long. acc. & swap-out with BR for acc.@high E

With antibend &ID Case（Circonference=1360.4m）

h=756，E0=6000，αp=1.35*10^{-5}，U0=4.5，Φ=π h αp E0

δacc=0.03，Vacc=δacc^2 Φ，φs=π



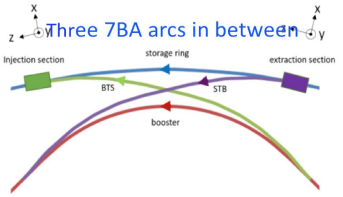
Δt=2.14ns between injecting and circulating beam(center to center)

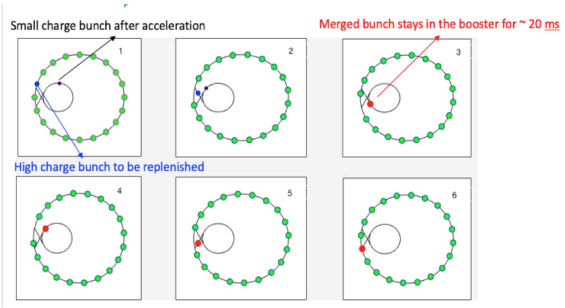
If considering effect of GolfClub Δt=2.4ns

Challenge of “swap-out” injection： a full charge injector

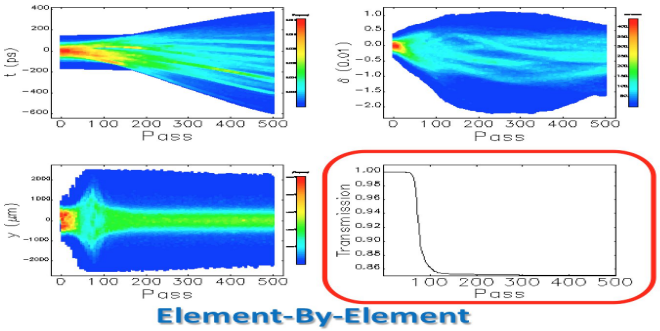
→ “Charge recovery” in the booster at 6 GeV

Two high-energy transport lines





- Single-bunch 15 nC, initial vertical offset $y\downarrow ini = 300\mu m$, initial bunch length $\sigma\downarrow t-ini = 40\ ps$, initial energy spread $\sigma\downarrow\delta-ini = 0.001$

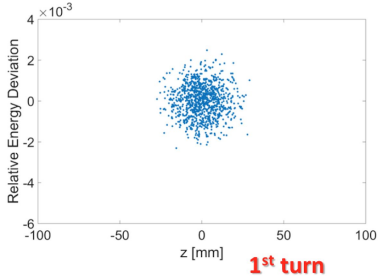


Element-By-Element

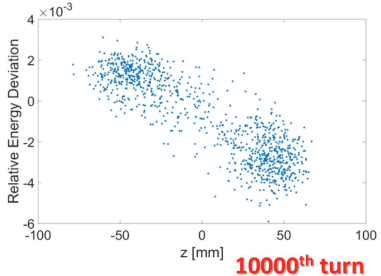
Transmission is only 84%

RF Modulation --- elegant tracking

- Phase Modulation
  - Modulation amplitude: 0.1rad;
  - Modulation frequency: ~26kHz, corresponding to 2 times synchrotron oscillation frequency;



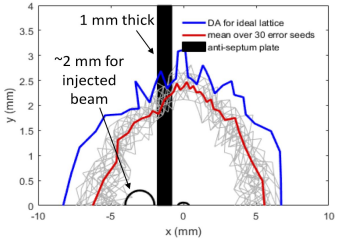
1st turn

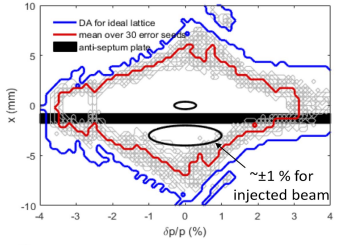


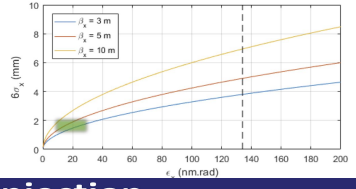
10000th turn

DIAMOND-II Accumulator (Ian Martin) Build new BR for use as AR @ low E

Diamond-II: Injection







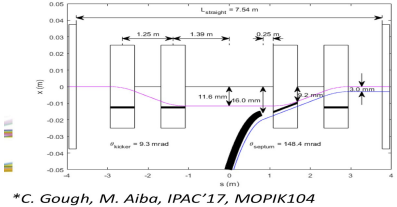
Requirements on injected beam:

- 3.5 GeV
- emittance in range 10-30 nm.rad
- bunch length in range 20-40 ps

Diamond-II: Injection

Proposal is to use 'anti-septum' storage ring injection scheme*

- Off-axis accumulation
- Standard 4-kicker bumps for stored beam
- Kicker 3 contains thin (1 mm) 'anti-septum' plate
- Appears like a drift space for injected beam
- Separation of stored / injected beams ~ 3mm

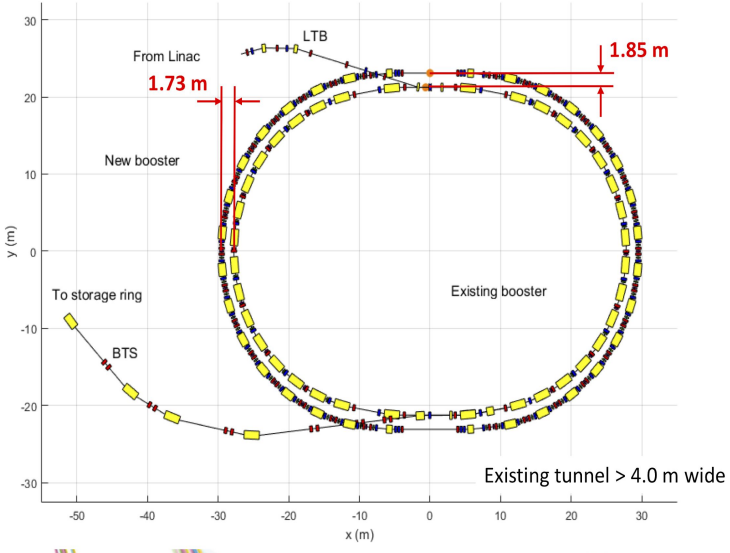


*C. Gough, M. Aiba, IPAC'17, MOPIK104

Parameter	Septum	Kicker
Magnetic Length	1.67 m	0.6 m
Bend angle	148.4 mrad	9.3 mrad
Bend radius	11.3 m	64.5 m
Magnetic field	1.04 T	0.18 T
Pulse shape	Full-sine	Half-sine
Pulse duration	160 μs	6 μs
Rep rate	5 Hz	5 Hz

diamond

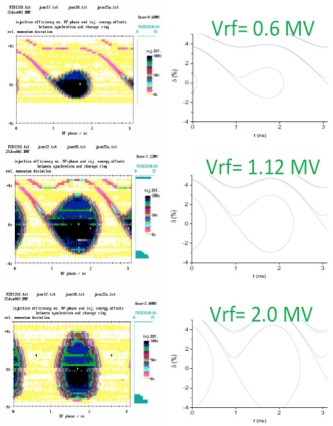
New Booster: Installation Strategy



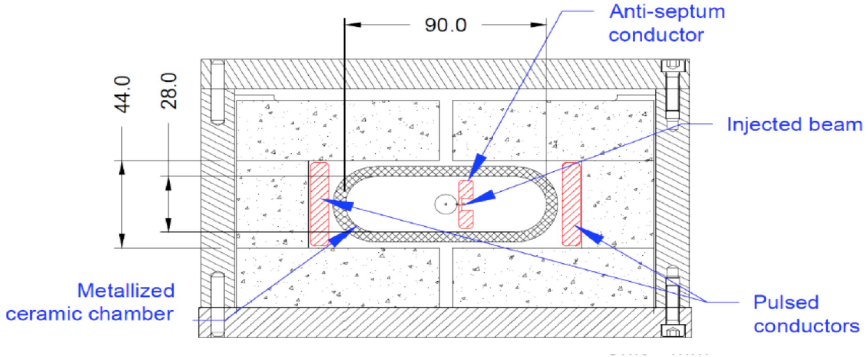
Parameter	Unit	Existing Booster	Upgraded Booster
Energy Range	GeV	0.1 to 3.0	0.1 to 3.5
Final Emittance	nm.rad	134.4	13.9
Circumference	m	158.4	170.5
Betatron Tunes	-	[7.18, 4.27]	[13.17, 4.37]
Natural Chromaticity	-	[-9.7, -6.3]	[-25.7, -10.1]
Final Energy Spread	-	7.3×10^{-4}	10.5×10^{-4}
Peak Energy Loss per Turn	MeV	0.58	1.64
Mom. Compact. Factor	-	25.2×10^{-3}	2.77×10^{-3}
Natural Bunch Length	ps	99.3	41.1
Peak RF voltage	MV	0.9	2.0
RF acceptance	%	0.24	0.58
Damping Times (τ_x, τ_y, τ_s)	ms	[5.46, 5.47, 2.74]	[2.43, 2.43, 1.22]
Repetition Rate	Hz	5	5

Injection for SLS-II (Masamitsu Aiba) A_z & anti-septum for off-axis @ low beta

- Results:

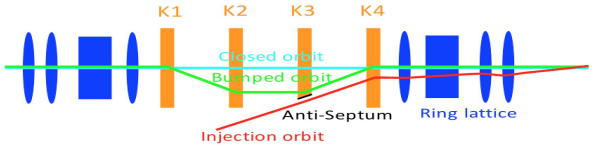


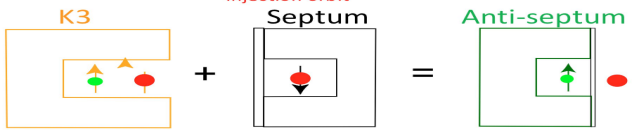
Observations:
- So-called "Golf-club acceptance" was clearly observed
- Good agreement with simulation except for V_{rf}=2.0 MV
- Given that the observed discontinuity of bucket this is attributed to a fragile transverse acceptance at large momentum deviation (more argument in next slide)



For technical aspects of septum and kicker, see Chris Gough's talk tomorrow morning

Baseline injection scheme (1)

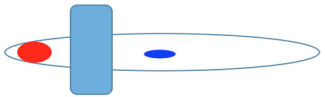




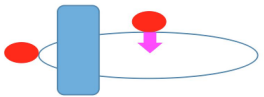
Anti-septum wall thickness can be 1 mm
- Stray field is excited at the other side of stored beam after injection beam passes
- Enough for mechanical stiffness
- Injection into ~5 mm aperture is possible

- Anti-septum + Longitudinal injection
  - Short pulse kicker can be placed at the next straight section
  - "One-arc dynamic aperture" must be large enough
  - Anti-septum injection = Quasi-on-axis injection → Reasonable kick angle, ~1 mrad for β_x = 4 m

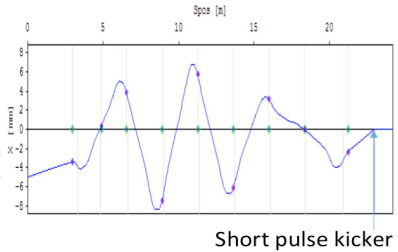
Anti-septum injection (high beta)



Anti-septum + Long. Inj. (low beta)



Injection beam orbit



Observations & Discussions

- Diamond has decided to optimize 6BA brightness through energy increase (3→3.5 GeV) rather than emittance decrease (160 pm rad @ 3.5 GeV in 561 m) → should help with IBS and Touschek
  - Does this only work for Diamond users (~20 keV)?
  - For other projects: can users' demands only be satisfied by minimizing emittance?
- Different types of RF gymnastics proposed for longitudinal injection (SOLEIL, HEPS, PLS-II)
- Lots of experience in proton machines, but in light sources what is there beyond Peter's/Masamitsu's measurements on BESSY-II? Where do we take confidence from?
- What about effect of transients?
  - ALS with only modest 3HC tuning & 10% gap → 20 deg transient ~= 120 ps
  - In 4GSRs: gaps might be shorter, use active HCs and/or FBs
- No matter if we do on-axis or off-axis, we need short-pulse kickers (developments need to start well ahead of projects)
  - Low frequency helps (100 MHz → 20 ns kicker pulses)
  - Short-pulse kickers allow for single-bunch injection → 1/h perturbation → injection becomes much more transparent regardless of
  - On the other hand, (short) gaps will likely remain necessary → trains remain an option → do flat-top requirements preclude short rise/fall times?
- Longitudinal accumulation appears to be much more robust compared to transverse accumulation, but will our machines still offer enough MA to enable it going forward (Bob Hettel: *"If you have ~~DA~~ MA left you haven't pushed your lattice hard enough"*)