ICFA

Oct. 9-12, 2014
Beijing, China

HF2014

WG6 Summary: Injectors and Injection

David RICE (Cornell U.)

and Yannis PAPAPHILIPPOU (CERN)

With contributions of

I. Koop (BINP), J. Seeman (SLAC), R. Talman (Cornell U.),

C. Zhang (IHEP) and the participants of the

Program

14:00 - 15:30 Parallel Session 8: WG 6 – Injectors and Injection

Convener: David Rice, Yannis Papaphilippou

14:00 **(1) CEPC injector** *22'*
Speaker: Prof. Chuang Zhang (IHEP)
Material: Slides

14:22 **(2) FCC-ee injector** *22'*
Speaker: Dr. Yannis Papaphilippou (CERN)
Material: Slides

14:44 **(3) Maintaining polarization in synchrotrons** *22'*
Speaker: Ivan Koop (BINP)
Material: Slides

15:06 **(4) Discussion** *22'*

15:30 - 16:00 Coffee (30')

16:00 - 17:30 Parallel Session 9: WG 6 – Injectors and Injection

Convener: David Rice, Yannis Papaphilippou

16:00 **(5) Topoff injection at PEP2** *22'*
Speaker: Dr. John seeman (SLAC)
Material: Slides

16:22 **(6) Injection with Pretzels at CESR** *22'*
Speaker: Mr. David Rice (Cornell U.)
Material: Slides

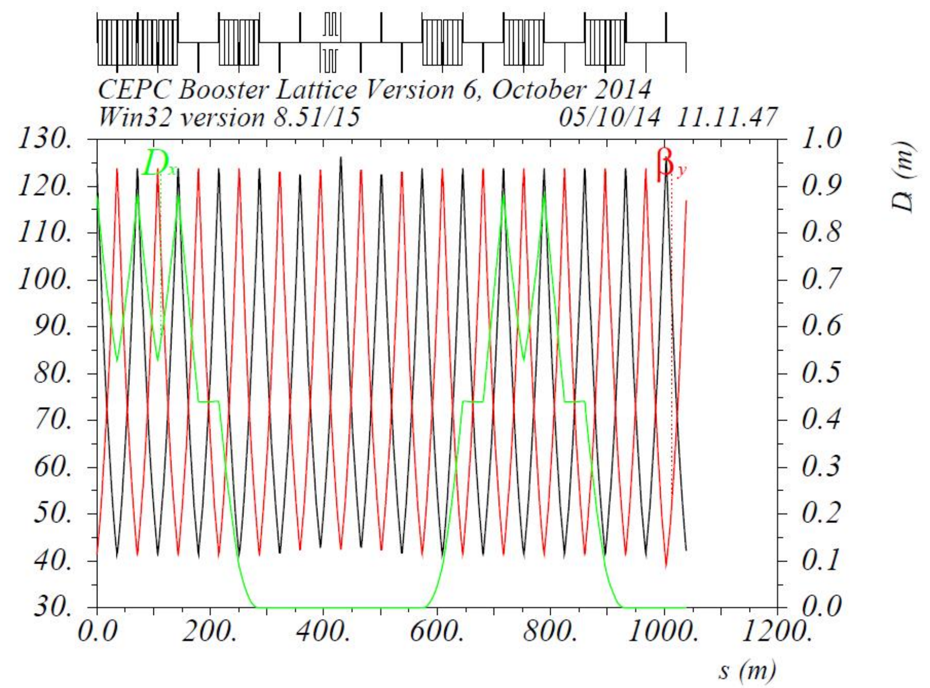
16:44 **(7) Lattice optimization for Top-Up injection** *22'*
Speaker: Prof. Richard Talman (Cornell U.)
Material: Slides

17:06 **(8) Discussion** *22'*

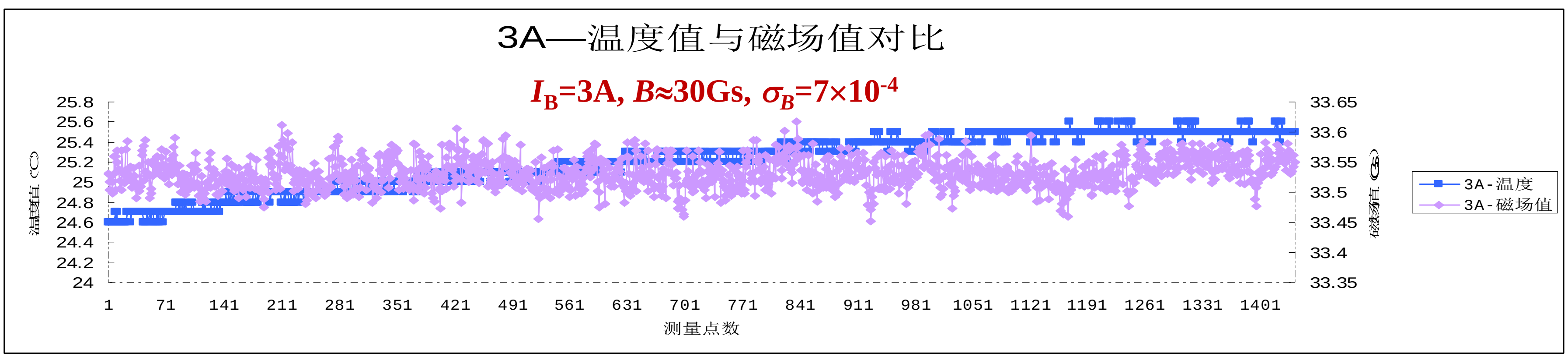
- Six talks of ~20min covering
  - CEPC and FCC injector design
  - Polarization preservation in synchrotrons
  - Top-up injection experience and optimization
  - Injection with pretzels

CEPC injector

- Conventional S-Band linac used also for recycling positrons, injection into Booster ring at 6GeV
- Boster cycle at 0.1Hz, single bunch injection (50 bunches), top-up of 5% of collider current decay, 90% injection efficiency
- Lattice based on arc FODO cells (shorter than the collider arc cell), including by-pass around the detectors, injection and extraction areas, confortable dynamic aperture
- Stability of 30Gaus dipole field at injection is of major concern (tests with BEPC dipole), mitigations with wiggling bends or higher energy considered



C. Zhang



C. Zhang

CEPC Injector Summary

- Conception design study on CEPC-Booster is carried out;
- There is no showstopper found in the design, in view point of lattice, bypasses, dynamic aperture, beam transfer and requirement to technical systems.
- The issues related to the low energy injection remain a central concern in the design.
- There are some technical challenges, such as the low HOM 1.3 GHz SC cavities, supports & alignment, as well as low cost components.
- The design study needs to be detailed and deepened.

Possible FCC-ee injector scheme

- Downgraded version of CLIC as pre-injector (or upgraded LIL/CTF3)
- Injection in the SPS @ 10GeV and accelerated to 20GeV (new RF system)
- SPS duty factor of 0.5 leaving time for fixed target proton physics
- Injected into the booster ring for full filling at 20min and compatible with shortest lifetime (FCC-ee top)
- Average power of ~1.3MW at extraction with density of ~18W/m
- Critical energies @ extraction as for the collider (up to 1.1MeV)
- Needs demanding shielding, absorption scheme and vacuum chamber design
- "Similar" geometry as main ring
- Low emittance @ extraction
- Ultra-low emittances @ injection with the same optics as for collider
  - Need detuned optics or working @ full coupling
- Same energy loss/turn as for collider (1MeV at injection)
- Bending field at injection of 61Gauss
  - Compensation of eddy currents, hysteresis effects and appropriate shielding from FCC-ee main magnets is needed
- Major challenge satisfying the diversity of parameters of the collider

Y. Papaphilippou

Outlook for FCC injector

- Flux requirements are very close to SuperKEKB and fully compatible with CLIC injector (using SPS as a damping ring)
- Ramp rate comfortable (can be increased to gain margin in flux requirements)
- First ideas for putting back leptons in already existing CERN injector complex
  - Co-habitation with the present (and future) LHC injectors is not given (impedance, super-cycle-sharing, new equipment,…)
- Top – up is challenging and should profit from synchrotron injection
  - Alternative injection schemes to be investigated, e.g. vertical injection
- Profit from low emittance rings collaboration and synergy with other projects at CERN (CLIC, LHeC,…) and abroad (SuperKEKB, X-ray storage rings,…)

Y. Papaphilippou

Spin transparent rotator for the solenoid partial Snake

For decoupling should be $T_x = -T_y$

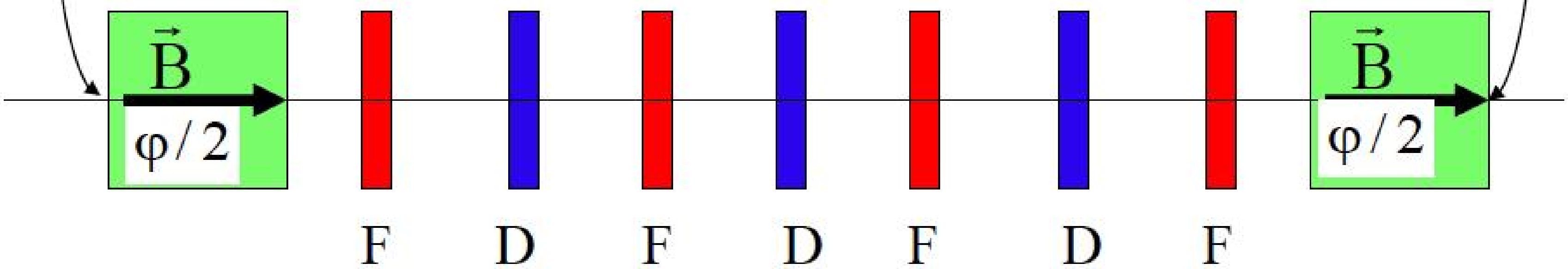
Litvinenko, Zholentz, 1980

$$T_x = \begin{pmatrix} -\cos\varphi & -2r\sin\varphi \\ (2r)^{-1}\sin\varphi & -\cos\varphi \end{pmatrix}$$

for the spin transparency!

(Koop et al., SPIN2006)

$$r = pc/eB$$



Two solenoids, each L=40 m B=5 T, provide spin rotation by $\varphi = 180^0$ at E=45.5 GeV. Extension to 120 GeV with B=10 T looks feasible.

All quads don't need to be skewed! Spin transparency require:

Full Snake: $\cos\varphi = -1, \quad \sin\varphi = 0;$ 90^0 - spin rotator: $\cos\varphi = 0, \quad \sin\varphi = 1$

I. Koop

Maintaining polarization in synchrotrons

- 3 to 9 snakes (odd number to have spin tune equal to 0.5) will ensure preservation of the polarization in a booster synchrotron of the FCC-ee complex up to 80-100GeV
- Minimization of spin tune chromaticity important (alternating solenoid field sign)
- Spin tracking is necessary, radiative effects to be included

I. Koop

Technical Items Needed for Top-Up injection

1) Measure each bunch charge in real time and determine when it needs refilling.
2) In the injector time a bunch to deliver it to the needed particular bunch (bucket) in the ring.
3) Inject the bunch(es) into the collider with very low losses.
4) Determine the injected beam backgrounds in the particle physics detector and find cures using collimation.
5) Develop methods to monitor relevant backgrounds in real time for accelerator operators to tune on.
6) Develop trigger masking for the detector physics taking by turn and with azimuthal variation.

J. Seeman

Conclusions

Top-up injection will work for a Circular Higgs Factory.

A full energy injector is needed because of beam lifetime.

A synchrotron injector will work the best but is more than is needed. (60 Hz)

A rapidly ramped storage ring is adequate. (4 sec)

A slowly ramped storage ring injector doesn’t make the luminosity constant enough.

The detectors will need to mask out the buckets with damping injected bunches during data taking.

J. Seeman

Injection with Pretzels @ CESR

- Several steps in design and operation have been taken to minimize injection losses.
  - Optics design – maximize minimum separation at crossings
  - Use sextupoles to split e+ / e- tunes, minimize coherent effects ($\Delta Q \approx 0.025$) –two more knobs beyond Q_x, Q_y
  - Move close to coupling resonance to increase σ_y of strong beam (not good for luminosity)
  - Use a one-turn kicker ("pinger") within a few turns of injection to reduce oscillation amplitude of injected bunches - small increase in stored beam oscillations.
  - Energy mismatch tuned for best filling efficiency
  - Filling one beam ≈ halfway, then the second and return to the first can keep bunch population more even.
  - Usual tuning of steering, closed orbit bumps, chromaticity…

D. Rice

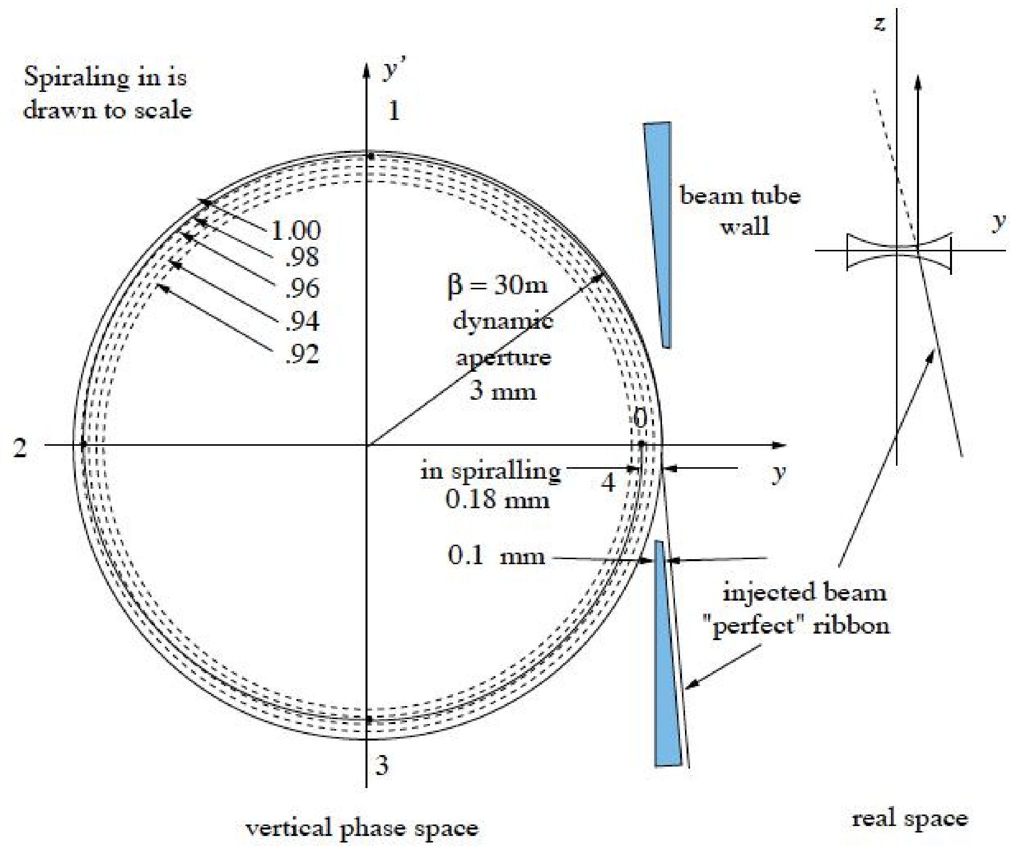
Injection with Pretzels @ CESR

- Injecting against counter-rotating beam adds challenges and (at least at CESR) is the most difficult aspect of multi-bunch operation, usually determining current limits.
- Once bunch populations become very uneven it can be difficult to recover "good" injection conditions.
- Several tuning tactics have been presented.
- For a ground-up design, careful simulation of the injection process, parasitic crossings, lattice nonlinearities and errors will be essential to a robust design.

D. Rice

Lattice optimization for top-off injection

- Due to fast damping and assuming a very thin septum (0.1mm) and vertical injection (very small vertical emittance), it is possible to injection vertical without need of bumpers and kickers
- Vertical dynamic aperture large enough (up to the septum) is only necessary



R. Talman

Lattice optimization for top-off injection

- Scaling the length cell with square root of bending radius, makes dispersion a constant $D \propto \frac{L_c^2}{R}$.
- In that case, quad strength, sextupole strength and DA are

$$q \propto 1/R^{1/2} \quad S \propto \frac{1}{R^{1/2}} \quad x^{\text{dyn. ap.}} \propto \frac{q}{S^{\text{arc chr.}}} \propto 1$$

$$\frac{x^{\text{dyn. ap.}}}{\sigma_x} \propto \frac{1}{1/R^{1/2}} \propto R^{1/2}$$

- For making injector emittances smaller and collider acceptances larger, shorten injector and lengthen collider cell length (increase focusing in injector and reduce in collider)

R. Talman

Summary of the…summary

- HF injectors have as major challenge the very low injector field (30-60Gauss)
- Same tunnel integration issues have not yet been examined
- Collective effects have not yet been studied, especially ultra-low emittances at injection may be an issue (may need detuned/coupled optics)
- The necessity of a damping ring for positrons in not obvious
- Odd number of snakes are needed for preserving electron polarization in BRs
- There is no obvious solution for polarized positron production
- Top-up is feasible (tailoring bunch charge from pre-injector is very important), compatibility of Pretzel with top-off has been demonstrated
- Masking events in experiments during top-off may be challenging due to HV equipment
- Alternative injection schemes have to be looked (vertical injection)
- May gain injection efficiency by increasing focusing in the injector and decreasing it the collider