ICFA

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HF2014

FCC-ee injector

Yannis PAPAPHILIPPOU, CERN

With contributions of

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F. Tecker, J. Wenninger, F. Zimmermann

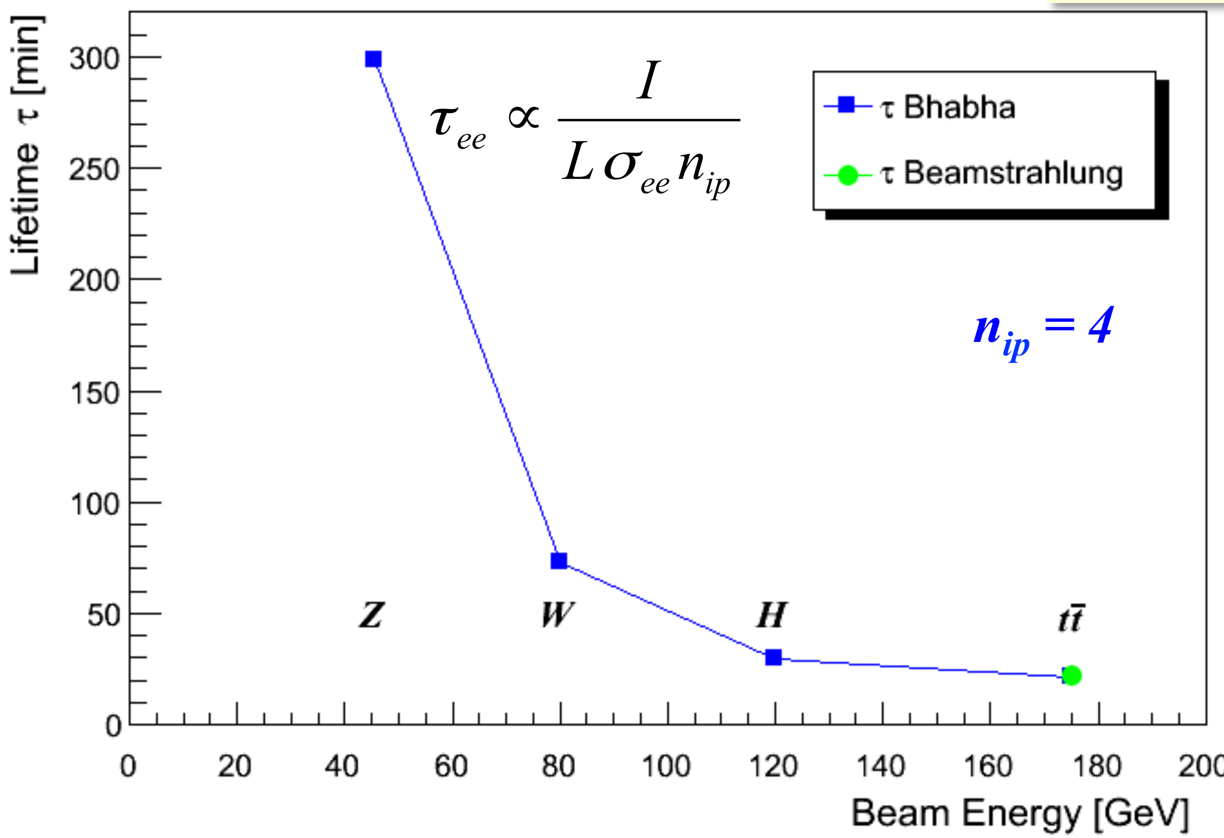
Outline

- Target parameters for injector
  - Repetition rate, particle flux
- LEP injector parameters
  - LIL and EPA, PS and SPS
- SUPERKEKB injector
- CLIC injector
  - CTF3 use and SPS as damping ring
- Tentative parameters for FCCee injector
- Top-up issues
  - PEPII, KEKB, X-ray storage rings
- Injection schemes
- Outlook and future work (injector work units)

FCCee Luminosity lifetime

- Lifetime from luminosity depends on radiative Bhabha scattering total cross-section
- For momentum acceptance of 2%, $\sigma_{ee} \approx 0.15$ b $\approx$ constant with energy (LEP). $\Rightarrow$ Lifetimes down to ~20 minutes.

Continuous injection (top-up)

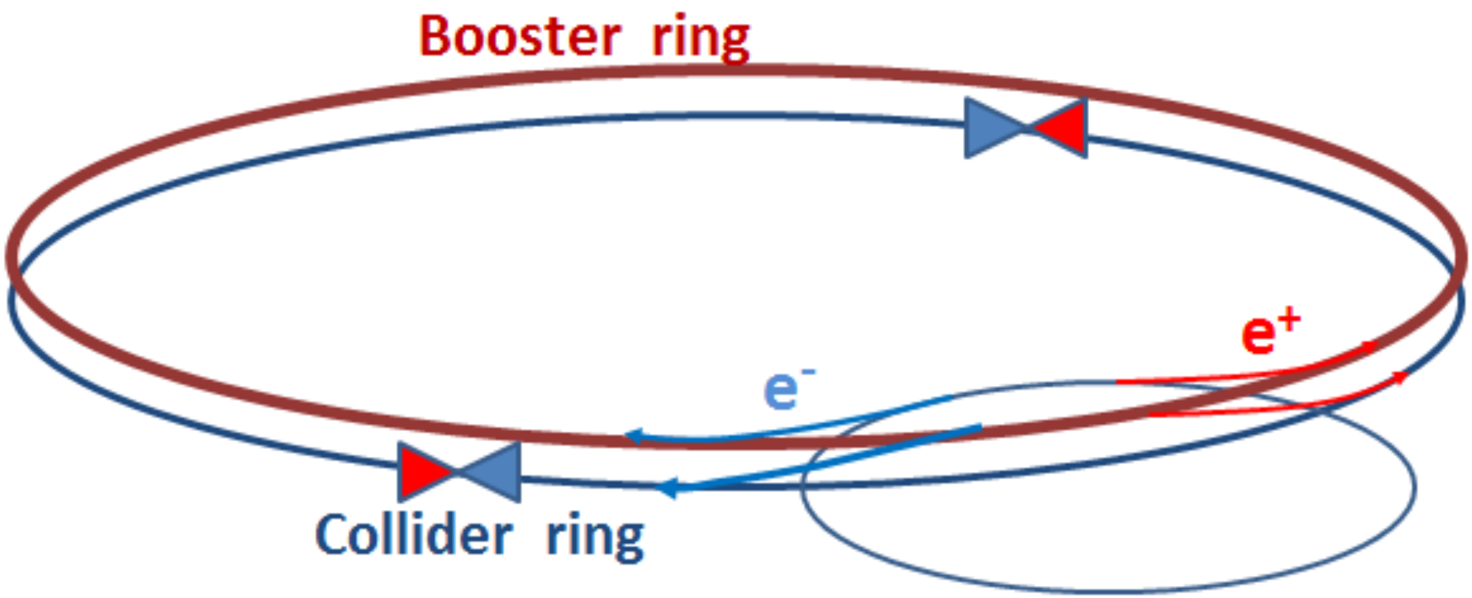


J. Wenninger

Booster ring considerations

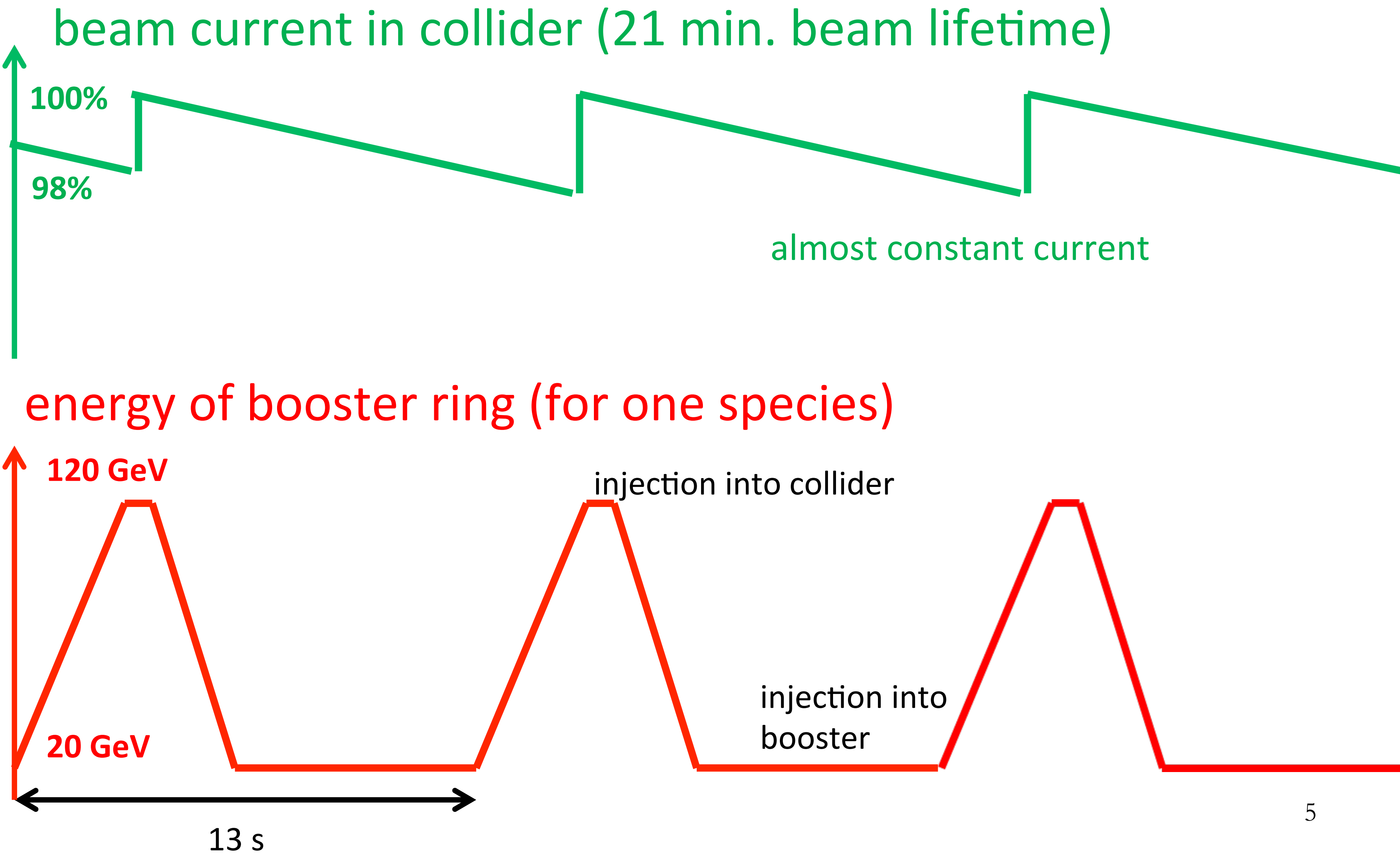
- Besides the collider ring(s), a booster of the same size (same tunnel) must provide beams for **top-up injection**.
- **Injector complex for e+ and e- beams of ~20 GeV**

J. Wenninger, FCC kick-off 2014



Schematic top-up cycle

F. Zimmermann, 2013



Target injector parameters

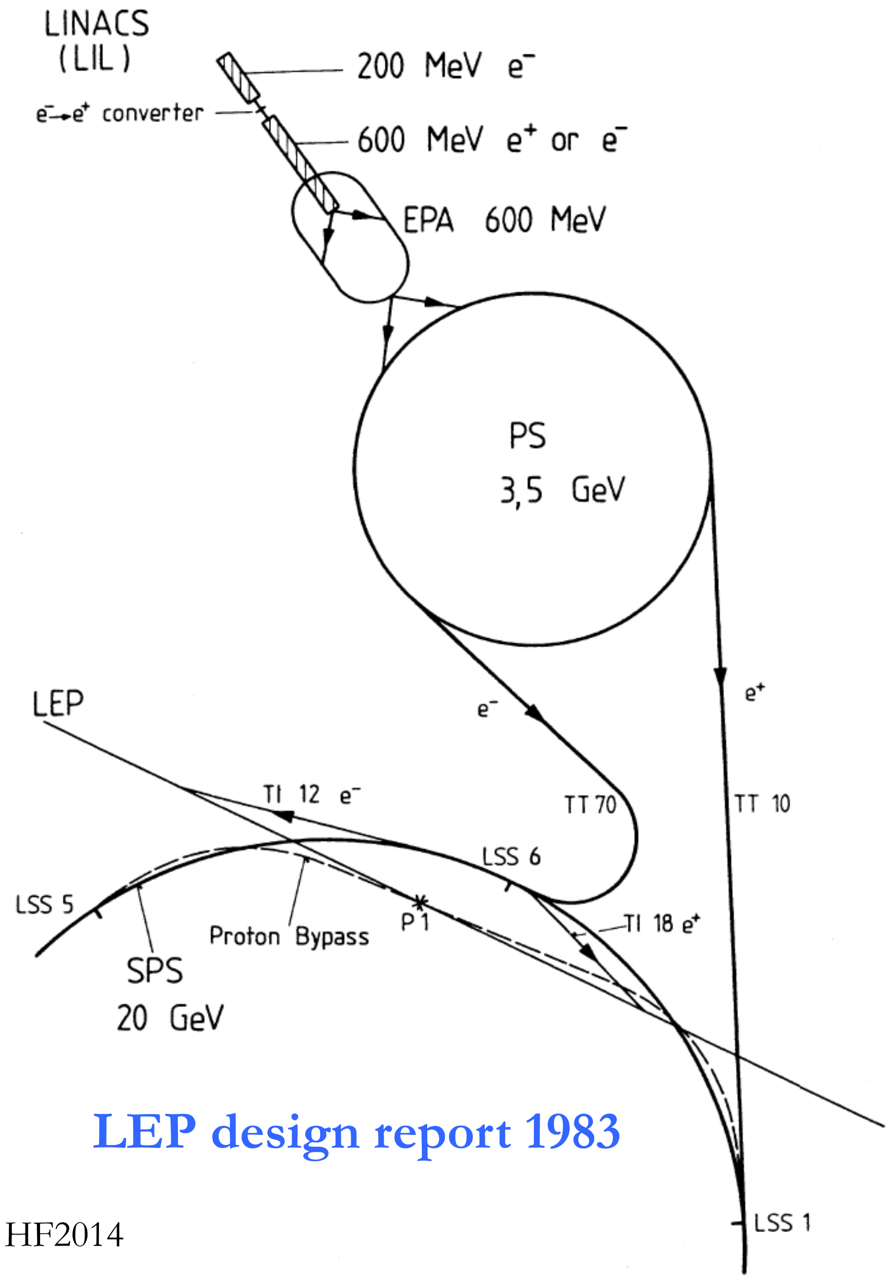
Parameter	Z	W	H	tt	LEP2
E [GeV]	45.5	80	120	175	104
I [mA]	1442	151	30	7	1
No. bunches	16700	4490	1360	98	4
Bunch population [10^{11}]	1.8	0.7	0.46	1.4	4.2
Lifetime [min]	298	73	29	21	434
Time between injections [sec]	361	88	35	25	263
Injected top-up bunch population [10^{11}]	601.2	62.9	12.5	2.7	0.34
Required particle flux for top-up [10^{11}p/sec]	**2.10**	**0.89**	**0.44**	**0.13**	**0.001**
Required particle flux for full filling [10^{11}p/sec]	**31.3**	**3.3**	**0.7**	**0.1**	**0.02**
Booster injector ramp rate [GeV/sec]	**5.2**	**12.2**	**20.4**	**31.6**	**17.1**

- For defining injector cycle and flux, assumed **2%** of current decay between top-ups
  - The top energy Fcc-ee defines the maximum time between injections/species (**25sec**)
  - Considering 50% duty factor (Interleaved e^+/e^- injection), injections should be made at a minimum rate of **~0.1Hz**
- For full collider filling (0.25mA/min for LEP), assumed **20min** of filling time and **80%** transfer efficiency along the injector chain
- Ramp rate for 0.1Hz injection considering linear ramp and short flat bottom and flat top (~100ms)
- Note that LEP2 injector parameters are obtained with the same assumptions

A bit of history…
The LEP injector complex

LEP injector layout

- Pre-injector included and e^+/ e^- linac at 500 MeV (LIL), and accumulator (EPA)
  - Dismantled and many equipment re-used in CTF3
- Transferred through PS (@3.5GeV) to SPS
- Transfer line for positrons as for protons (TT2-TT10) and anti-proton line used for electrons (TT70-TT60, completely dismantled, as well as BT elements)



LEP design report 1983

LEP pre-injector parameters

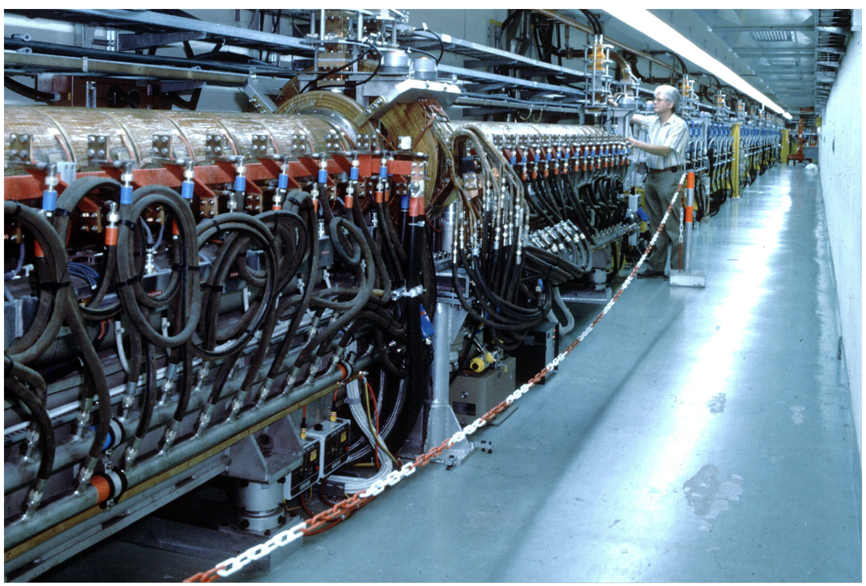
L. Rinolfi

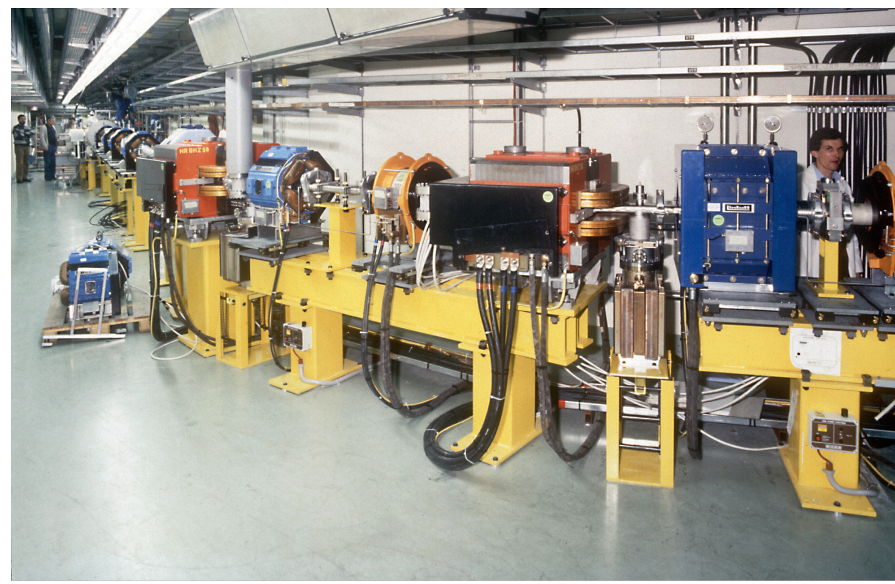
Parameters	LIL e-	EPA e-	LIL e- for e+	EPA e+
energy [GeV]	0.2 to 0.7	0.500	0.200	0.500
bunch population [10^{10}]	2		0.5 to 20	
bunch length [ps]	15		15	
bunch interval [ns]	0.333		0.333	
beam pulse length [ns]	10		10 to 50	
Beam sizes [mm] (rms)	3		1	
Flux [10^{11} p/s]	20			0.7
repetition rate [Hz]	100	0.83	100	0.09
Number of bunches		1 to 8		1 to 8
Max. bunch population [10^{11}]		4.5		3

- Flux for electrons quite high, much lower for positrons
  - Injection efficiency through the injectors almost 100%
  - **Betatron** Injection efficiency to LEP was **~50%** (filled machine)
  - **Alternative** injection scheme was necessary for pushing injection efficiency to **~85%** (see below)
- Positron accumulation time quite long

LPI – LEP Pre-Injector

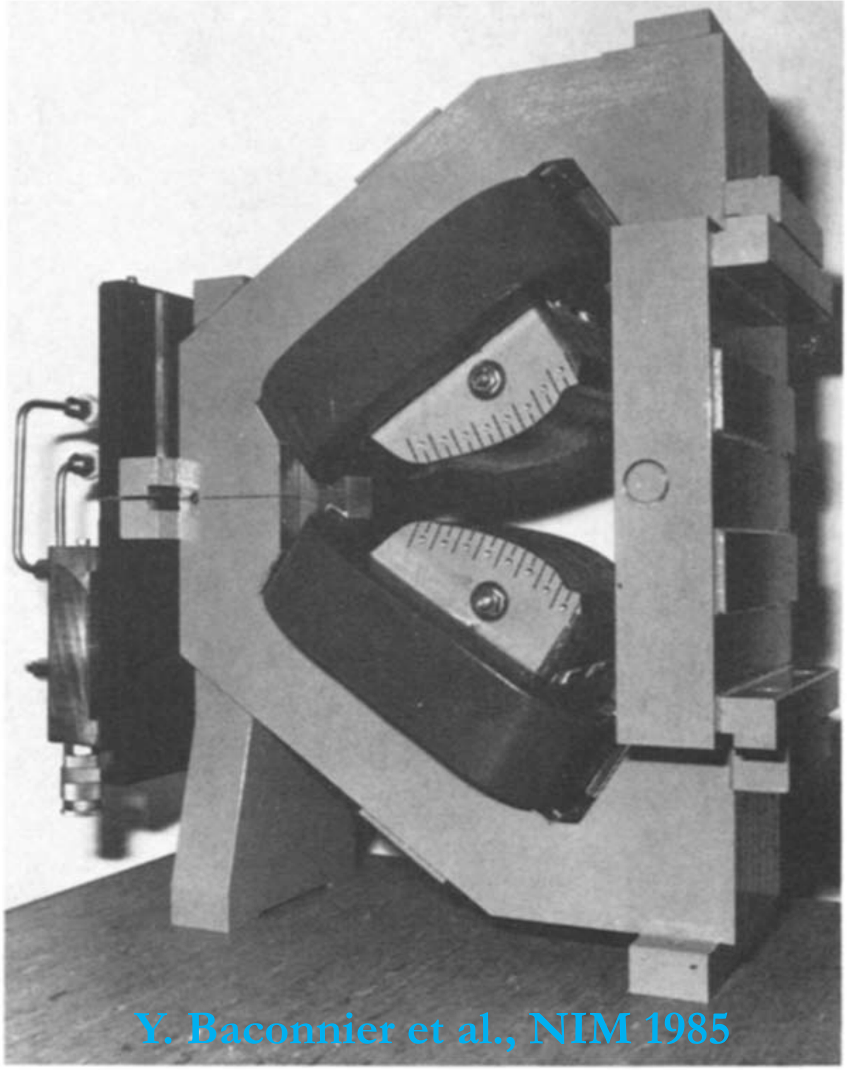
- 500 MeV e-/e+ into the PS
- EPA storage ring had 1/5 of PS circumference (40π m=125.66m) => multi-bunch transfer to PS
- 19.1 MHz RF system, 50 kW, h=8
- e+ production by 200 MeV linac + W-target





Leptons through PS to SPS

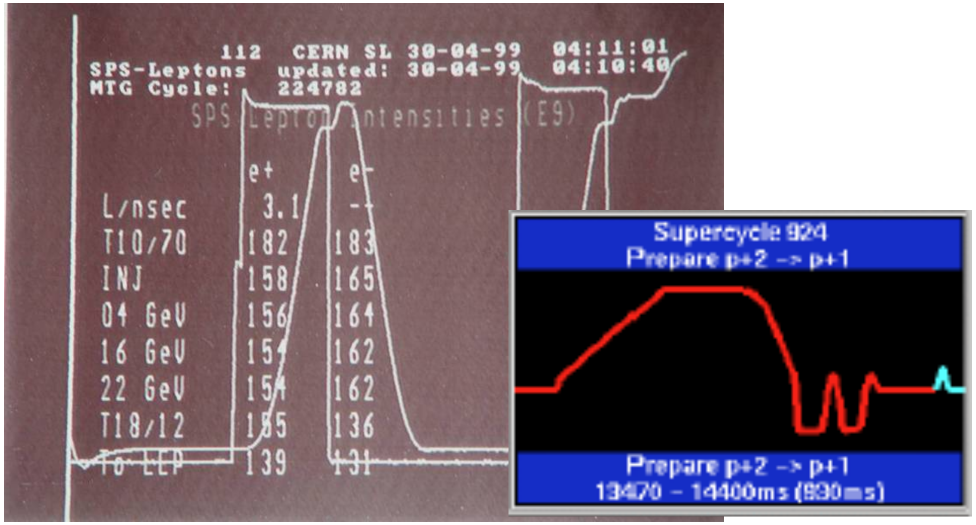
- Injecting at 500 MeV and extracting at 3.5 GeV
- 114 MHz RF system (2x500kV, 2x50kW), taken out in 2001
  - Robinson wigglers controlling damping partition (beam stability and reduced energy spread)
- RF had special 'expansion' of the longitudinal emittance



Y. Baconnier et al., NIM 1985

SPS as LEP Injector

P. Collier – Academic Training 2005



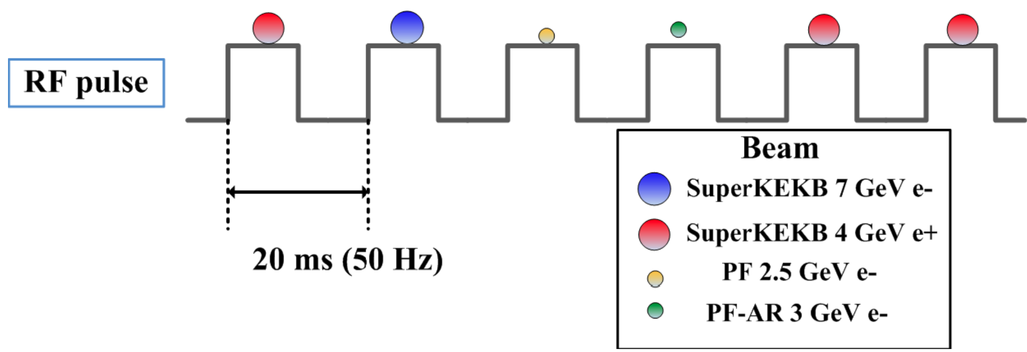
- LEP filling interleaved with FT proton operation
  - Initially supercycle of **14.4s** and later **12s**
- 4 cycles with 4 bunches ($2e^+$, $2e^-$) evolved to 2 cycles with 8 bunches (~$\mathbf{2.5\times10^{10}}$ p/b)
- Energy to LEP: 18 → 20 → 22 GeV
- Lots of RF for leptons (200MHz SWC, 100MHz SWC, 352MHz SC), all **dismantled** for impedance reduction
- 2 Extractions in Point 6 towards LEP

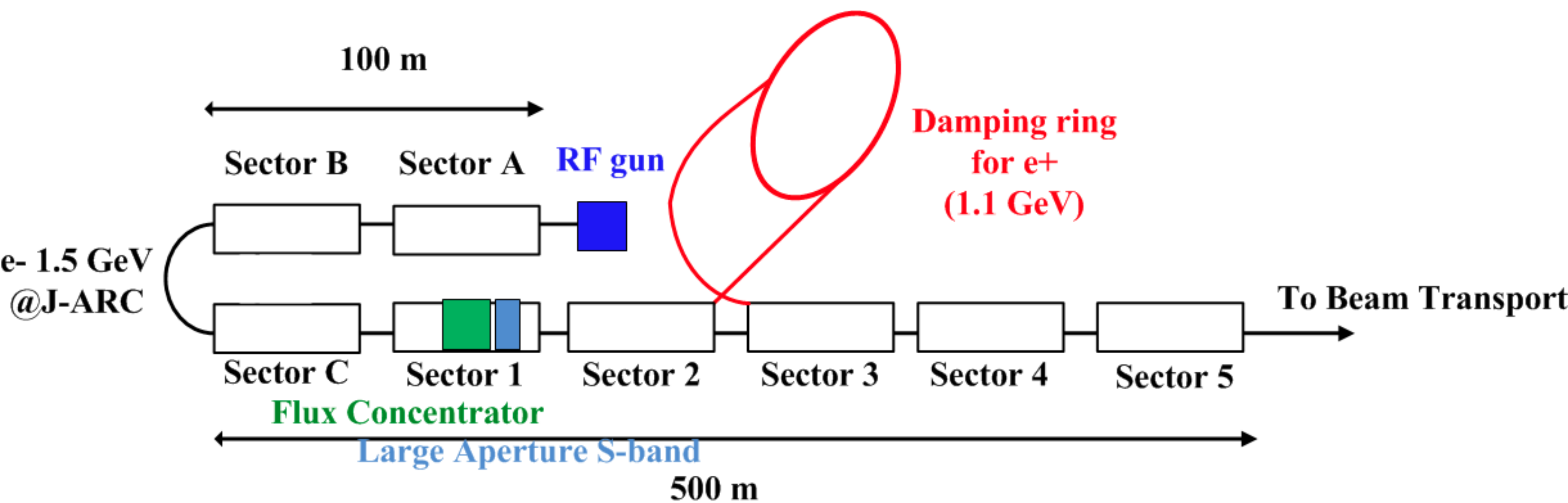
- Flux of $\mathbf{1.7\times10^{11}}$ p/s for each cycle
  - An order of magnitude lower if taking into account machine duty cycle (12s supercycle)
- **Incompatible** with lepton flux requirements for Z and W production (full machine filling)
- Need to be stretched for H and tt
- Lepton acceleration to **20GeV not possible** (~**30MV RF** needed and **not compatible** with present proton program)
- Ramp rate of **62.3GeV/s** provides factor of 2 margin, i.e. even **5sec cycle** possible
  - Ramp rate can be even faster due to low field requirements (maybe ~1Hz possible)

SuperKEKB injector

- Lifetime of 6min necessitates top-up
- Injector should serve 4 rings
  - Repetition rate 50Hz
- Positron flux rate at **2.5×10^{12}** p/s is **compatible** with FCC-ee needs
- Commissioning of the injector has already started
  - **Collaboration** with KEK colleagues essential for gaining experience

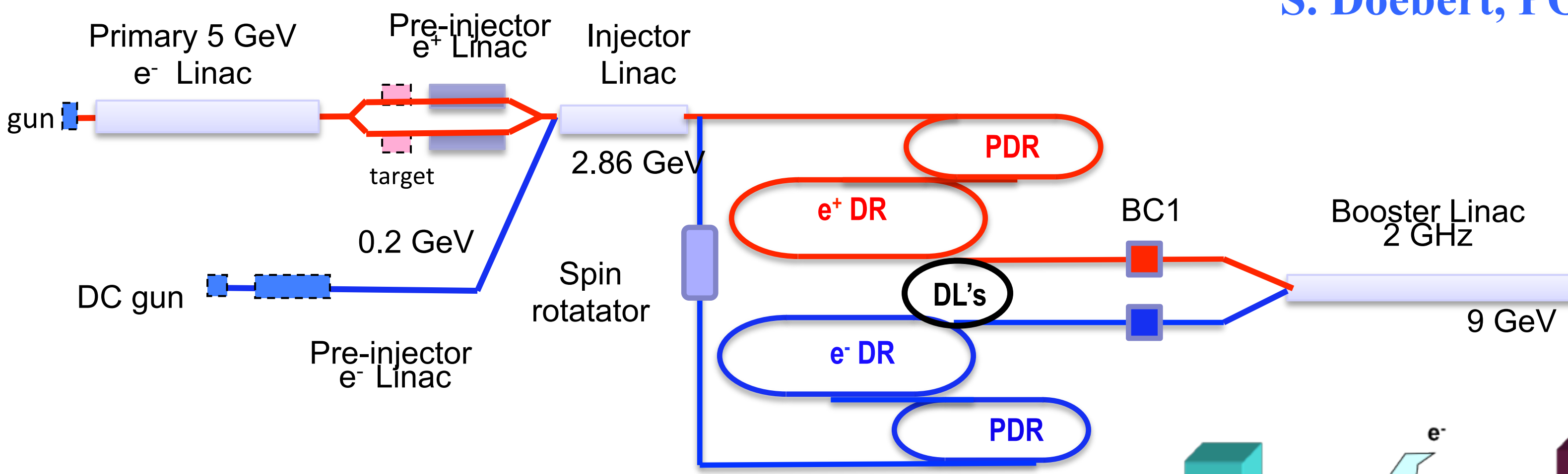
K. Oide, FCC-ee 2014

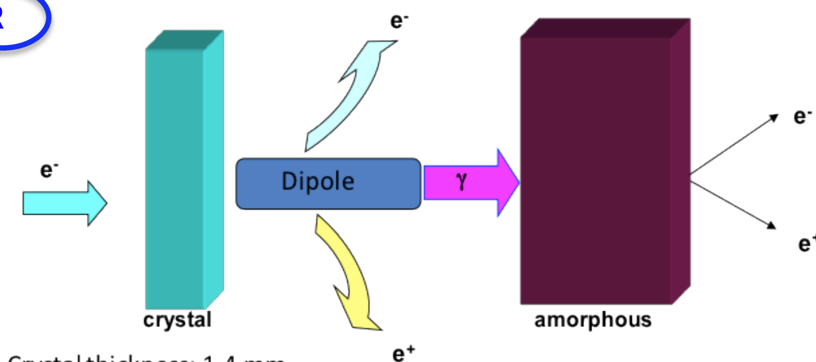




CLIC Main Beam Injector Complex

S. Doebert, POSIPOL 2013





- Two hybrid positron sources (only one needed for 3 TeV collider)
- Common injector linac
- All linac's at 2 GHz, bunch spacing 1 or 2 GHz before the damping rings

Crystal thickness: 1.4 mm
Oriented along the <111> axis

Distance (crystal-amorphous) d = 2 m

Amorphous thickness e =10 mm

Target Parameters Crystal		
Material	Tungsten	W
Thickness (radiation length)	0.4	χ_0
Thickness (length)	1.40	mm
Energy deposited	~1	kW

Target Parameters Amorphous		
Material	Tungsten	W
Thickness (Radiation length)	3	χ_0
Thickness (length)	10	mm
PEDD	30	J/g
Distance to the crystal	2	m

Positron flux for linear colliders

L. Rinolfi

	SLC	CLIC (3 TeV)	CLIC (0.5 TeV)	ILC (RDR)	LHeC (pulsed)	LHeC ERL
Energy [GeV]	1.19	2.86	2.86	5	140	60
e^+/ bunch (at IP) [10^9]	40	3.7	7.4	20	1.6	2
e^+/ bunch (aft. capture) [10^9]	50	7	14	30	1.8	2.2
Bunches / macropulse	1	312	354	2625	100 000	NA
Rep. Rate (Hz)	120	50	50	5	10	CW
Bunches / s	120	15600	17700	13125	10^6	20×10^6
e^+ flux [10^{14}p/s]	0.06	1.1	2.5	3.9	18	440

- SLS injector positron flux flux already compatible with FCCee needs
- CLIC injector positron flux **satisfies FCC-ee requirements** for all energies
  - Leaves a lot of margin for capture and transfer losses
  - Design quite mature (un-polarized positrons)
  - Need **damping ring** (for positrons)
  - Different bunch structure and **20GeV linac** for injecting into booster ring
- **LHeC** is orders of magnitude above requirements (challenging design)

Reviving lepton injector complex @ CERN

SPS as damping ring

- Reviving old ideas, when SPS was running also as a LEP injector
- More recent ones, serving as e+ DR for LHeC
- Can be used for for testing components and interdependencies in similar beam conditions in the presence of synchrotron radiation (scrubbing with leptons?)

Evans and Schmidt, 1988

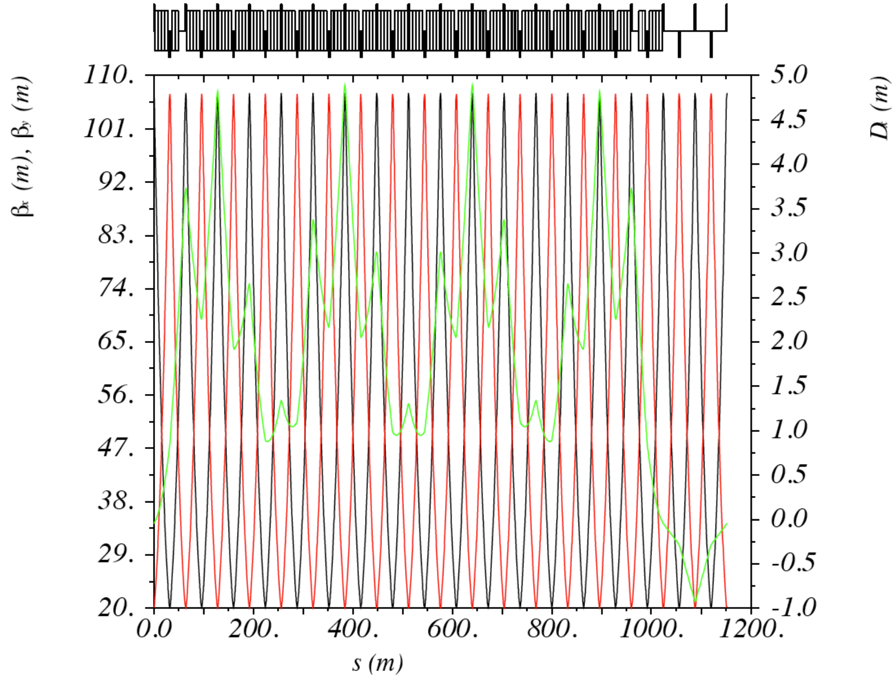
A	B	F	G	H	I
VARIABLES		*WITH WIGGLER*		Intrabeam scattering	
ETA	0.0018	brho	13.3424	ep	0.001637
VOLTS(V)	4.00E+07	wiggler deflection	0.00356	A	3.9E-06
Q VALUE	27	Bending radius	14.04463	k	0.005958
MOMENTUM COMPAC	0.0018	2*pi*rho^2	1239.369	a	0.003439
BETA (V/C)	1	F	0.005544	d	0.997034
ENERGY DPN JE	2	***Parameters With wiggler on***		lnc2a	8.492016
RADIAL DPN JX	1	Energy loss per turn	5.51E+06	Tx(sec)	1.37E+00
ENERGY(EV)	4.00E+09	Energy damping time	1.67E-02	Tz(sec)	1.23E+02
PARTICLES/BUNCH	5.00E+09	Horizontal damping time	3.34E-02		
HORIZONTAL BETA	40	Energy spread	9.11E-04		179.3655
VERTICAL BETA	40	Synchrotron Tune	0.168447		85.4419
HARMONIC NUMBER	10000	Bunch length sigma	1.07E-02		532.8773
BWIGGLER (TESLA)	0.95	Sigmasquared/beta	3.63E-10		27.19585
Pole Length	0.05	Normalised emittance	2.84E-06		179.3655
Total Wiggler Length	300	Norm long emit	7.64E-02		

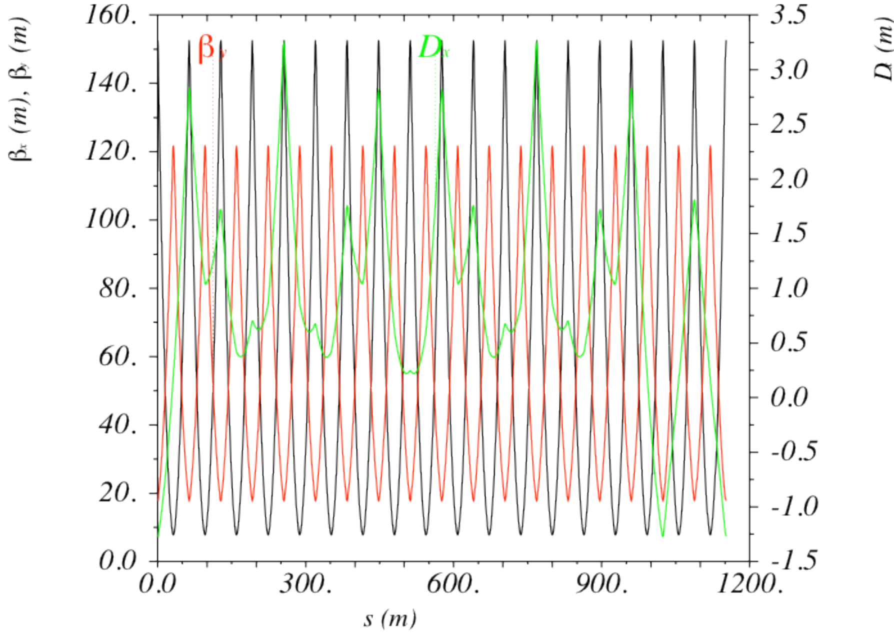
Parameter [unit]	High Rep-rate	Low Rep-rate
Energy [GeV]	10	7
Bunch population [10^9]	1.6	1.6
Bunch spacing [ns]	2.5	2.5
Number of bunches/train	9221	9221
Repetition rate [Hz]	100	10
Damping times trans./long. [ms]	2/1	20/10
Energy loss/turn [MeV]	230	16
Horizontal norm. emittance [μm]	20	100
Optics detuning factor	80	80
Dipole field [T]	1.8	1.8
Dipole length [m]	0.5	0.5
Wiggler field [T]	1.9	-
Wiggler period [cm]	5	-
Total wiggler length [m]	800	-
Dipole length [m]	0.5	0.5
Longitudinal norm. emittances [keV.m]	10	10
Momentum compaction factor	10^{-6}	10^{-6}
RF voltage [MV]	300	35
rms energy spread [%]	0.20	0.17
rms bunch length [mm]	5.2	8.8
average power [MW]	23.6	3.6

LHeC design report 2011

SPS low emittance optics

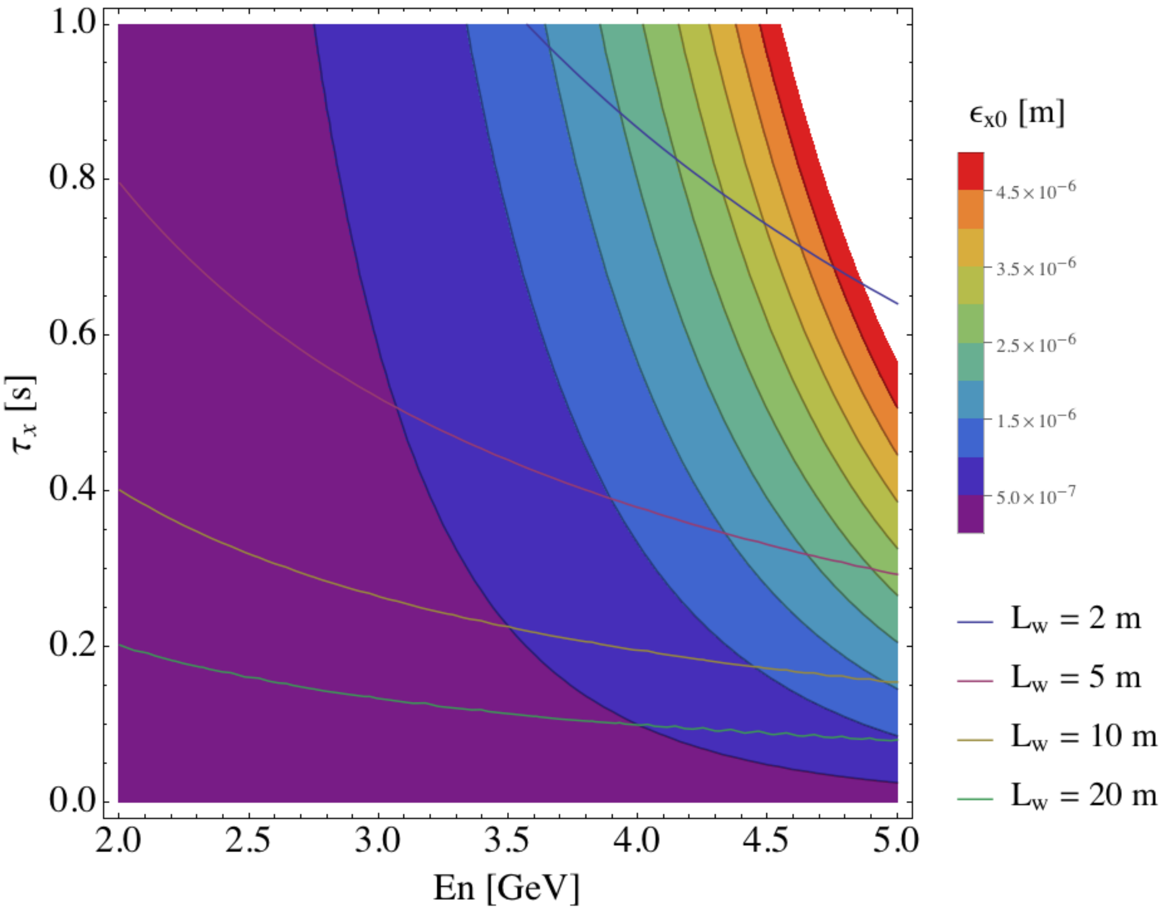
- SPS is an all FODO cell lattice (6 sextants), with missing dipole
- Usually tuned to 90 deg. phase advance for fixed target beams (**Q26**) and since 2012 to 67.5 deg (**Q20**) for LHC beams
- Move horizontal phase advance to 135(3π/4) deg. (**Q40**)
- Normalized emittance with nominal optics @ 3.5GeV of 23.5μm drops to 9μm (1.3nm geometrical)
  - Mainly due to dispersion decrease
  - Much below the FCC-ee emittance target, but lower emittance helps with transfer efficiency
- Damping times of 9s
- Natural chromaticities of -71,-39 (from -20,-27)





Emittance scaling

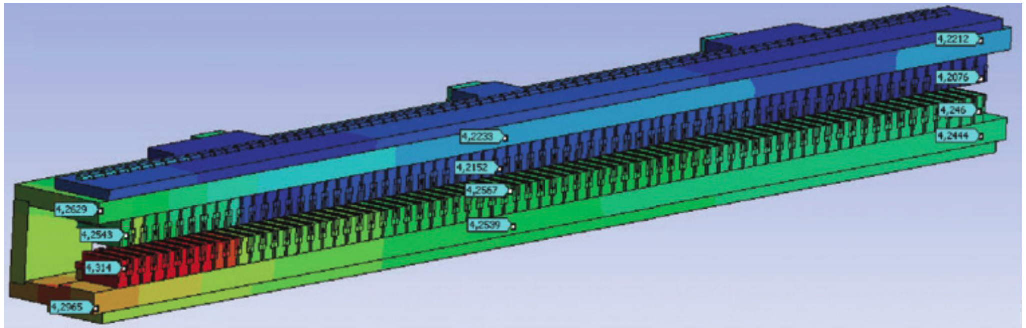
- Energy and damping time can be parameterised with equilibrium emittance, for different wiggler lengths
- Ultra-low emittance achieved in energy range between 2 to 5GeV

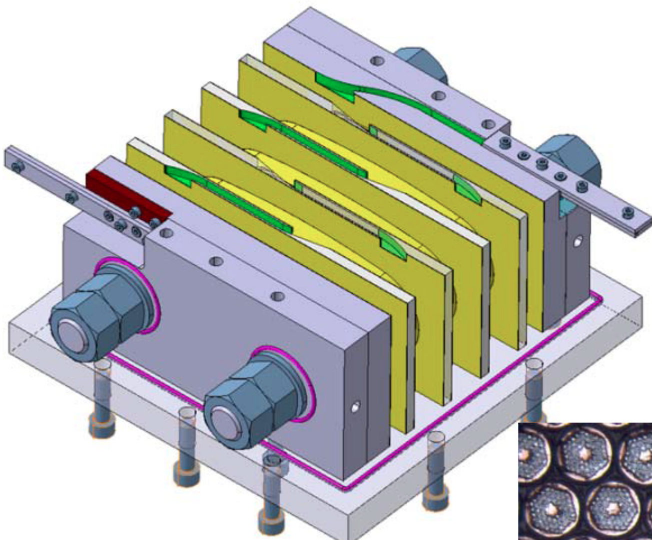


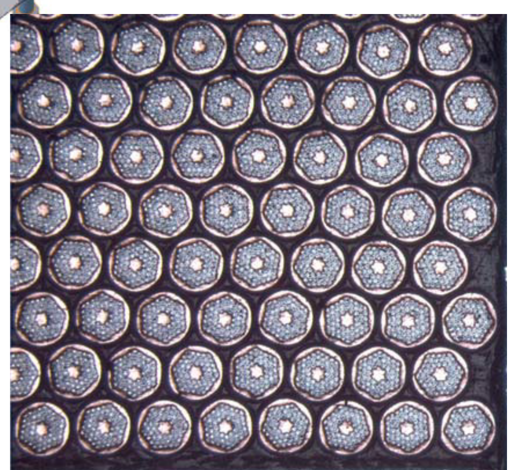
- A few meters of damping wigglers can be used (and higher energy) for short damping times
- Available RF voltage sufficient up to ~10GeV (without wigglers)

SC wiggler development

A. Bernard, P. Ferracin, N. Mesentsev, S. Hillenbrad, L. Garcia-Fajardo, et al. CLIC workshop 2014



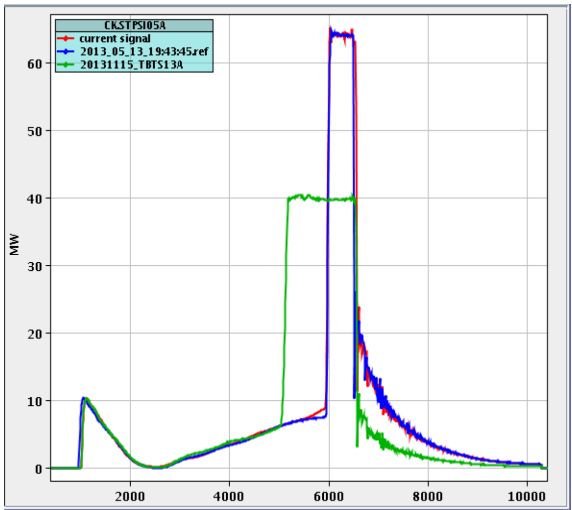




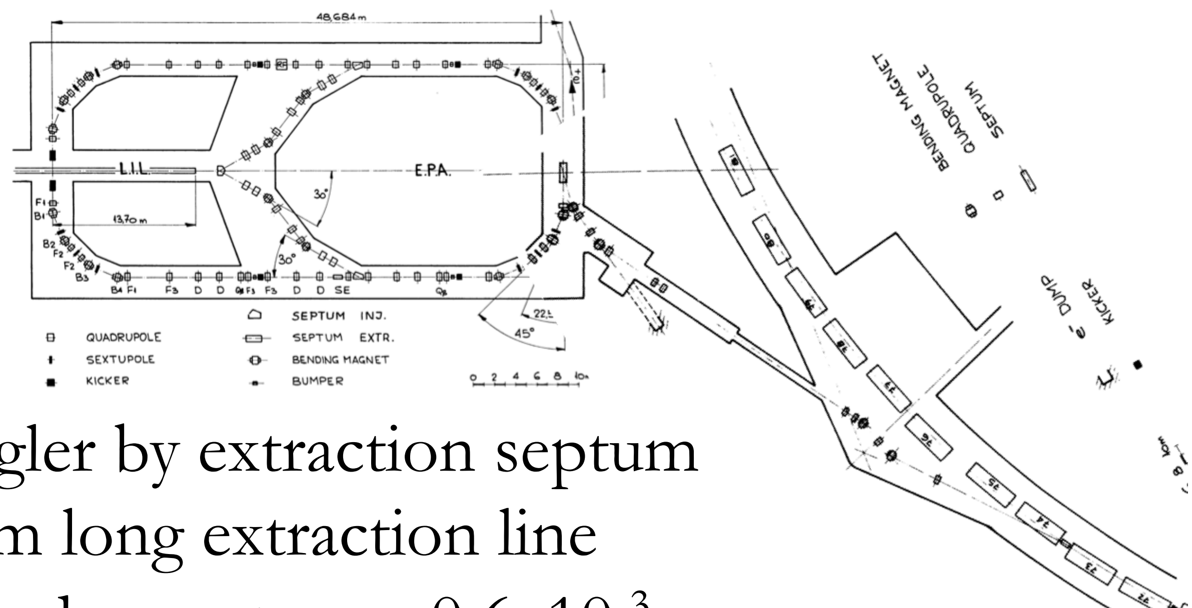
- Two paths of R&D
  - NbTi wire, horizontal racetrack, conduction cooled (BINP/KIT collaboration)
  - Nb_3Sn wire, vertical racetrack, conduction cooled (CERN)
- Full NbTi length prototype
  - Higher than 3T, 5.1cm period, magnetic gap of 18mm
  - Under production by BINP to be installed in (summer 2014) in ANKA for beam tests
  - Operational performance, field quality, cooling concept
- First Nb_3Sn vertical racetrack magnet (3-period) tested in 2011
  - Reached 75% of max. current
  - Limited by short coil-to-structure (insulation)
  - New short model under development (optimised impregnation,

CTF3 injection into PS

R. Corsini, F. Tecker,
CLIC workshop 2014



- CTF3 has ~125 MeV (full beam-loading)
- Short pulse + low charge + 1 additional MKS > gain of ~ 3 in energy
- final energy: ≥ 380 MeV
- CR & TL1 bends good up to 450 MeV



- Replace CR wiggler by extraction septum
- Rebuild ~40-50m long extraction line
- Had energy spread acceptance: $0.6\mathrm{x}10^{-3}$

From the linac to SPS

Linac bunch structure

Single bunch (train) – need laser

≥ 5 ns spacing

≥ 25 ns spacing

3 GHz short bunch pulse (possibly repeated a few tin

R. Corsini, F. Tecker,
CLIC workshop 2014

PS RF acceptance

- Maximum energy acceptance: $\left(\frac{\Delta E}{E_s}\right)_{\max} = \mp\beta\sqrt{-\frac{2e\hat{V}}{\pi h \eta E_s}}$
- E=400 MeV, η=-α=-0.027
- present 200 MHz system, h=420, 8*30kV
- => $\Delta E/E < 5.7\ 10^{-3}$

- 40/80 MHz systems have 2*/3*300kV, respectively
- => ΔE/E < 2% / 1.75%

- 40/80 MHz do not match with the CR rev. frequency
- maybe direct injection into PS

- Emittances looks OK even for direct transfer for e- (but not for e+)
- Bunch charge limitations to be checked without Robinson wigglers
- Transfer lines PS > SPS OK for e+, not for e- (transfer lines)
  - Generation of e+
- RF cavity, extraction septum in CR (case of accumulation) ?
- Injection/extraction elements in PS, SPS

FCC-ee injector parameters

Possible FCC-ee injector scheme

- **LINACS** and positron production a downgraded version of the one for CLIC (or upgraded LIL/CTF3)
  - **2GHz, 50Hz repetition rate,** less than **10^9** p/b
- Trains with **3200 bunches** (320 for the Higgs and 98 for top production) injected **8 times** (7 for the top) in the SPS @ 10GeV in the required **50MHz** bunch structure and accelerated to 20GeV
  - Need new RF system in the SPS (50MHz?)
- SPS duty factor of **0.5** (apart for top) leaving time for fixed target proton physics
  - 5 cycles of 1.2s in a supercycle of 12s
- Injected into the booster ring (flat bottom of 6s or 2.4s) to be accelerated in **3s** to required extraction energy for FCC-ee
- **Filling time** for full filling **20min**
- **Top-up** compatible with lifetime (**25s** for FCC-ee top)

Tentative FCC-ee injector parameters

Accelerator	FCCee-Z		FCCee-W		FCCee-H		FCCee-tt	
Energy [GeV]	45.5		80		120		175	
Type of filling	Full	Top-up	Full	Top-up	Full	Top-up	Full	Top-up
LINAC # bunches	3200				320		280	
LINAC repetition rate [Hz]	50							
LINAC RF freq [MHz]	2000							
LINAC bunch population [10^8]	5.9	0.4	0.6	0.2	1.2	1.2	0.02	0.04
# of LINAC injections	8						7	
SPS/BR bunch spacing [MHz]	50							
SPS bunches/injection	80				8		7	
SPS bunch population [10^{10}]	2.35	0.16	0.25	0.08	0.49	0.49	0.10	0.14
SPS duty factor	0.5						0.29	
SPS / BR # of bunches	640/3200				64/320		49/98	
SPS / BR cycle time [s]	1.2 / 12						1.2 / 8.4	
Number of BR cycles	50	15	50	3	50	1	71	1
Transfer efficiency	0.8							
Total number of bunches	16700		4490		1360		98	
Filling time (both species) [sec]	1200	360	1200	72	1200	24	1193	16.8
Injected bunch population [10^{10}]	18	0.36	7	0.14	0.46	0.092	14	0.28

Booster Ring parameters

Top Energy [GeV]	45.5	80	120	175
Cycle time [s]	12			
Circumference [m]	100000			
Bending radius [m]	11000			
Injection energy [GeV]	20			
Dipole length	10.5			
Emittance @ injection [nm]	2.81	0.10	0.01	0.01
Emittance @ extraction [nm]	14.5	1.65	1.0	1.0
Bending field @ injection [G]	61			
Bending field @ extraction [G]	138	243	361	531
Energy Loss / turn @ injection [MeV]	1.287			
Energy Loss / turn @ extraction [MeV]	34.5	329.4	1667.6	7542.6
Long. Damping time @ injection [turns]	15543			
Long. Damping time @ extraction [turns]	1320	243	72	23
Average current [mA]	36.1	3.8	0.8	0.1
Average power @ injection [kW]	46.4	4.9	1.0	0.2
Average power @ extraction [MW]	1.24	1.26	1.26	0.88
Average power over 1 cycle [kW]	100	105	105	104
Power from dipoles @ extraction [W]	189	192	191	189
Power density on bends @ extraction [W/m]	18	18	18	13
Critical energy [MeV]	0.02	0.10	0.35	1.08
Radiation angle [μrad]	11.2	6.4	4.3	2.9

- "Similar" geometry as main ring to fit in the same tunnel
  - Need to by-pass experiments
- Low emittance @ extraction obtained quite naturally due to the small bending angle
  - Good for injection efficiency and top-up
- Ultra-low emittances @ injection if keeping the same optics as for collider
  - 10pm for higgs and top
  - Need detuned optics or working @ full coupling to avoid collective effects

Booster Ring parameters

Top Energy [GeV]	45.5	80	120	175
Cycle time [s]	12			
Circumference [m]	100000			
Bending radius [m]	11000			
Injection energy [GeV]	20			
Dipole length	10.5			
Emittance @ injection [nm]	2.81	0.10	0.01	0.01
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Radiation angle [μrad]	11.2	6.4	4.3	2.9

- Energy loss/turn determined by energy and ring geometry
  - Same as for the collider at extraction (~1MeV at injection)
- Bending field at injection of **61Gauss**
  - Has to remain low as energy loss/turn at flat top is already quite high
  - Compensation of eddy currents, hysteresis effects and appropriate shielding from FCC-ee main magnets is needed

Booster Ring parameters

Top Energy [GeV]	45.5	80	120	175
Cycle time [s]	12			
Circumference [m]	100000			
Bending radius [m]	11000			
Injection energy [GeV]	20			
Dipole length	10.5			
Emittance @ injection [nm]	2.81	0.10	0.01	0.01
Emittance @ extraction [nm]	14.5	1.65	1.0	1.0
Bending field @ injection [G]	61			
Bending field @ extraction [G]	138	243	361	531
Energy Loss / turn @ injection [MeV]	1.287			
Energy Loss / turn @ extraction [MeV]	34.5	329.4	1667.6	7542.6
Long. Damping time @ injection [turns]	15543			
Long. Damping time @ extraction [turns]	1320	243	72	23
Average current [mA]	36.1	3.8	0.8	0.1
Average power @ injection [kW]	46.4	4.9	1.0	0.2
Average power @ extraction [MW]	1.24	1.26	1.26	0.88
Average power over 1 cycle [kW]	100	105	105	104
Power from dipoles @ extraction [W]	189	192	191	189
Power density on bends @ extraction [W/m]	18	18	18	13
Critical energy [MeV]	0.02	0.10	0.35	1.08
Radiation angle [μrad]	11.2	6.4	4.3	2.9

- Average current considered for full filling, from a fraction to ~**36mA**
- Average power at injection up to **46kW**
- Up to ~**1.3MW** at extraction
- Power density up to ~**18W/m**

Booster Ring parameters

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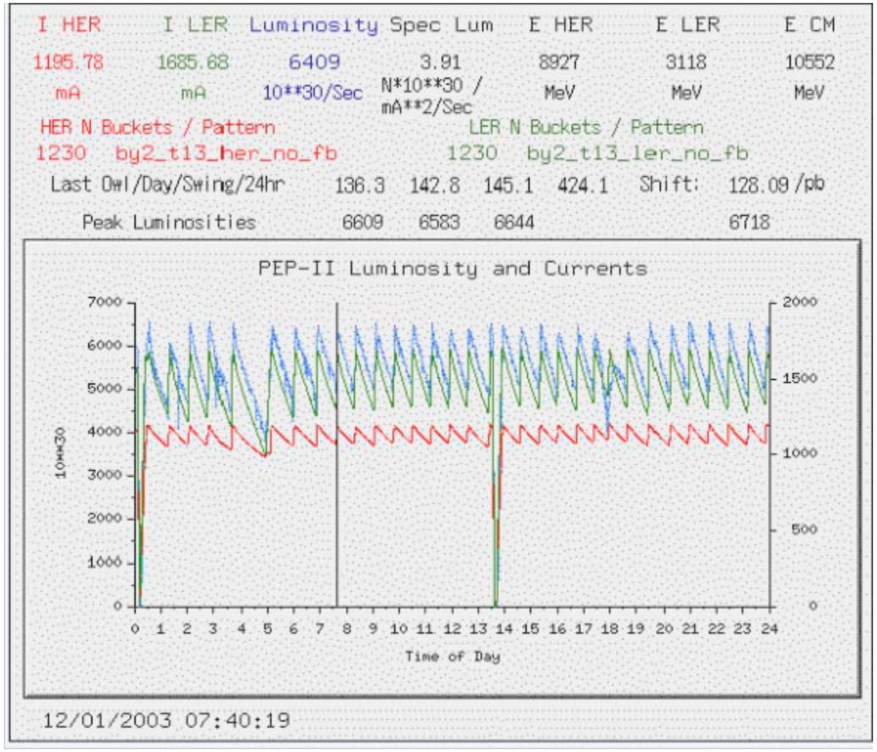
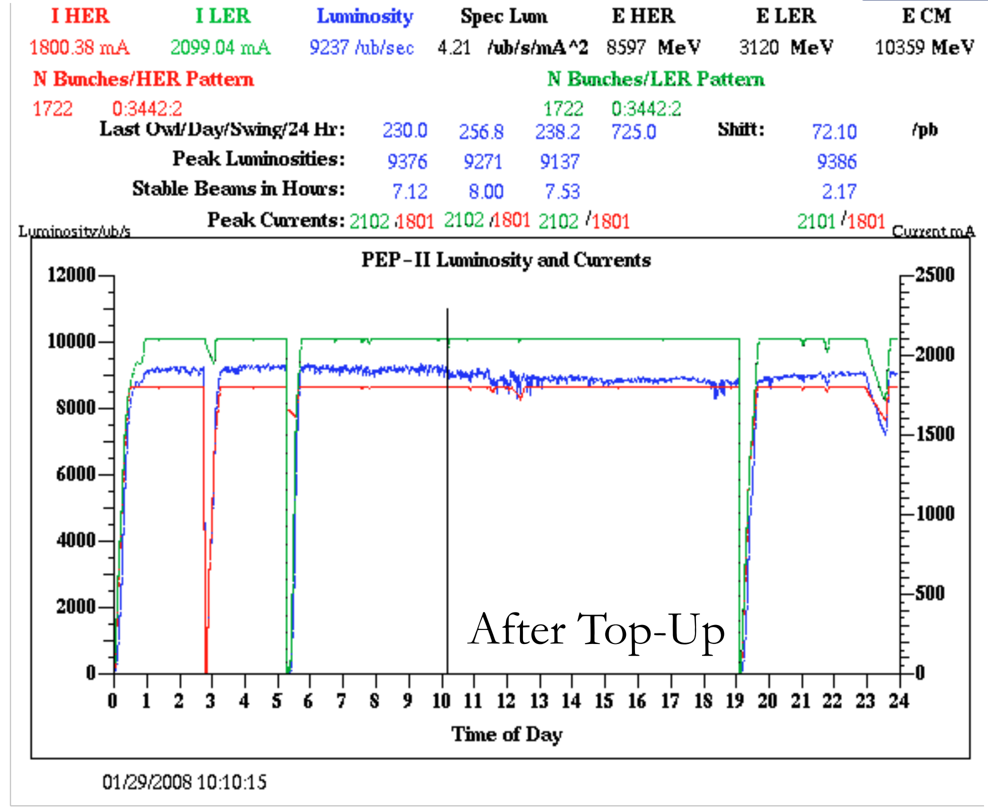
- Critical energies @ extraction as for the collider (up to **1.1MeV** for highest energy)
- Vertical radiation angle of a few μrads
- Needs demanding shielding, absorption scheme and vacuum chamber design

Top-up and injection scheme considerations

Top-up at PEP-II/BaBar



Before Top-Up

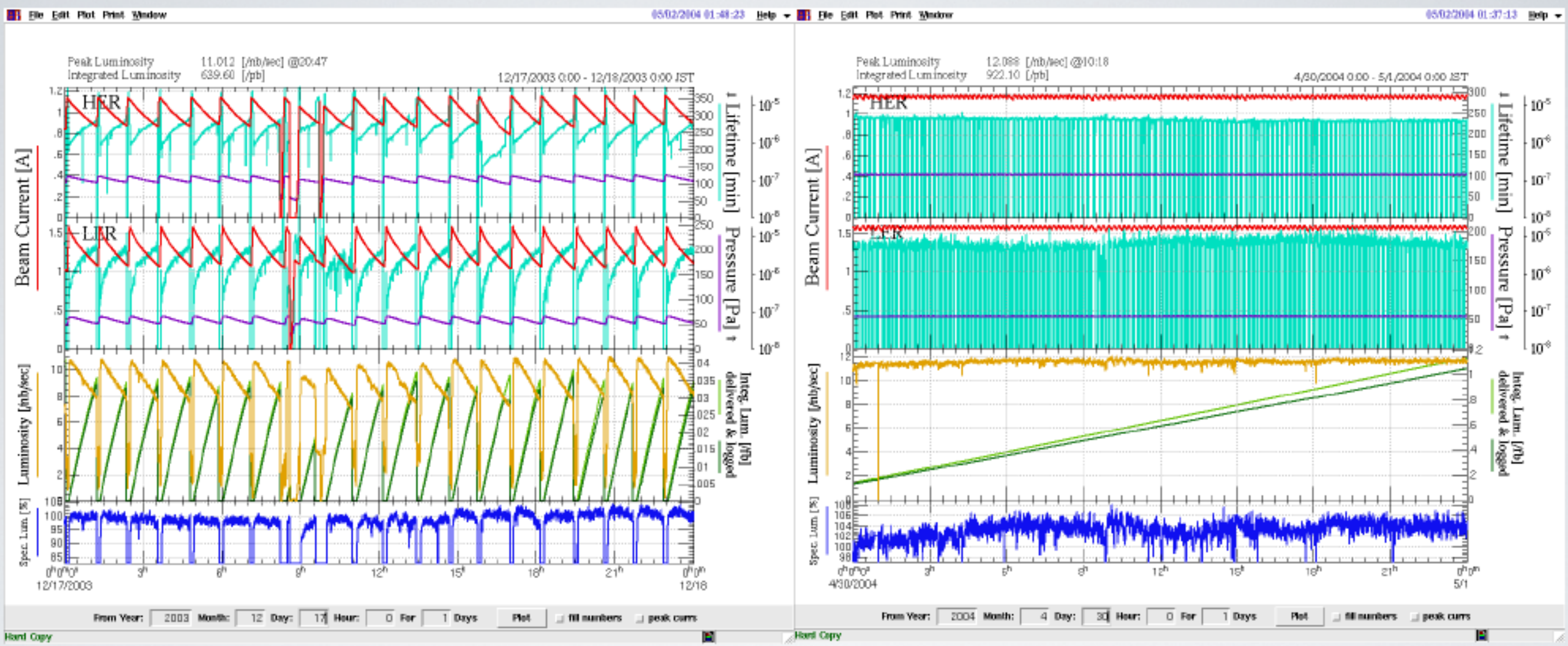


See J. Siemann talk

- Background signals provided by the BaBar detector gated on actual injection pulses
- Systematic improvements of the electron beam from the LINAC
- Reduction of the distance of the injected beam from the closed orbit
- Trajectory stabilization feedback
- Both ring kicker systems were upgraded

Top-up at KEKB

K. Oide, FCC kick-off 2014



a day before top-up a day after top-up

- Top-up improved the integrated luminosity from 640 pb/day to 920 pb/day in 2004 (eventually reached 1480 pb/day in 2009).
- Machine becomes more stable and less aborts, as the stored beam current is nearly constant.
- Thus the luminosity tuning became easier.

Top-up injection for light sources

J.L. Revol, 2012

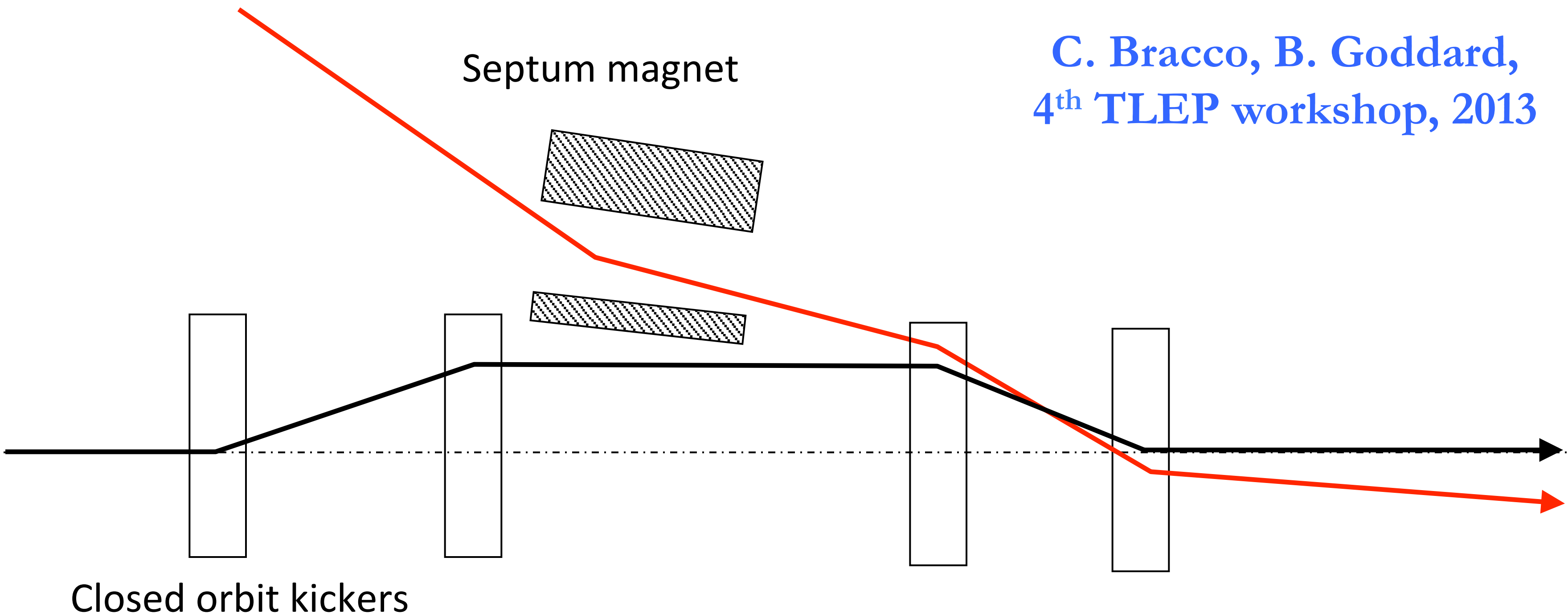
Two Operating Modes		Stability	Number of shots	Time between injection	
Injection at fixed Delta I	SPring 8	0.03 %	One	≈ 2 to 3 mn *Hybrid 10 to 30 sec*	One shot
Injection at fixed Delta I	Bessy	0.13 %	One	≈ 20 to 30 sec	One shot
Injection at fixed Delta I	Soleil	0.5 %	One	≈ 2 to 5 mn	One shot
Injection at fixed Delta I	Elettra	0.3 %	20 shots	*≈ 6 mn at 2 GeV* *25 mn at 2.5 GeV*	Few shots
Injection at fixed Delta I	SLS	0.5 %	10 shots	≈ 1 to 2 mn	Few shots
Injection at fixed Delta I	Petra	1 %	40-50 low charge shots	≈ 8 mn *1 mn (timing mode)*	Few shots
Injection at fixed Delta Time	APS	≈ 0.5 %	One	1 and 2 mn	One shot
Injection at fixed Delta Time	Diamond	≈ 0.8 %	Few	10 mn	Few shots
Injection at fixed Delta Time	ESRF	≈ 20%	400	12 hours	Few shots

- Perturbations due to top-up
  - Bump closure, septum shielding, booster magnet field shielding, thermal drifts, blind-out of experiments during injection, reliability of booster ring, BT elements failures, orbit feed-back,…
- Study alternative injection schemes and innovative kicker technology

Betatron injection

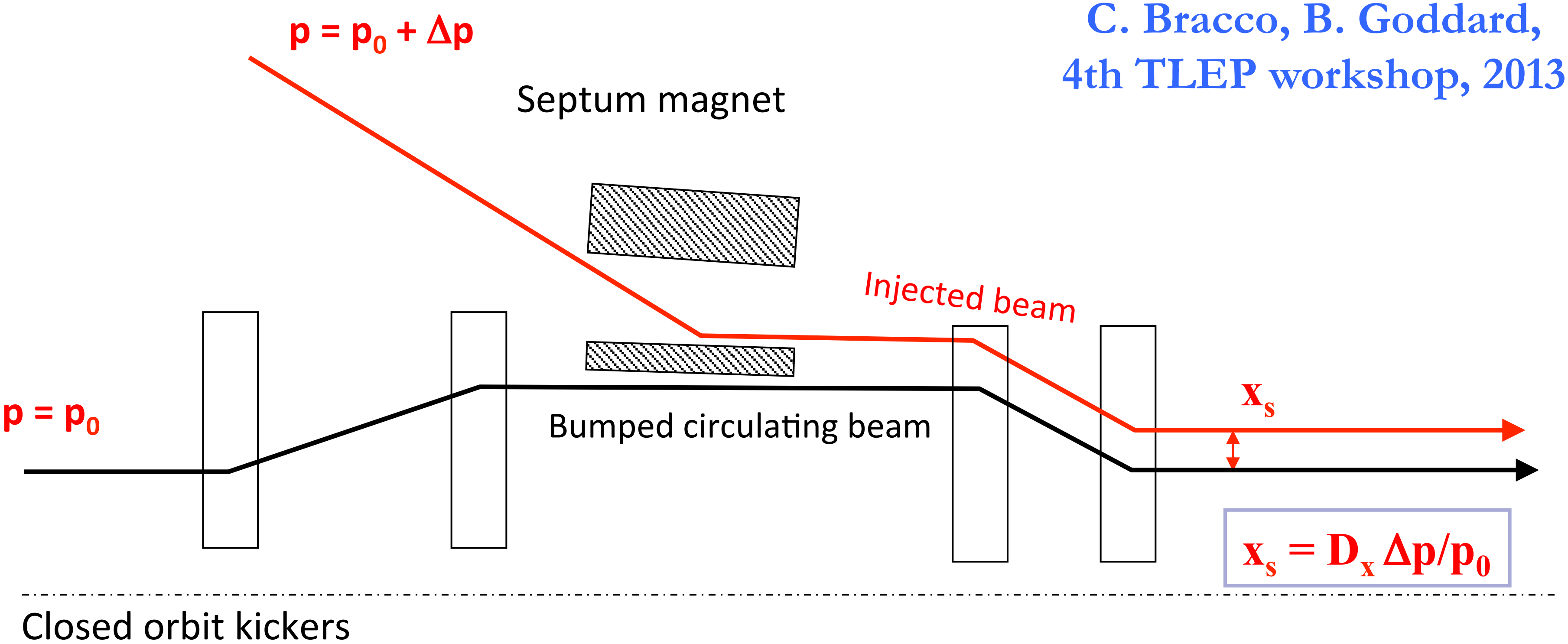
- Beam is injected with a position/angle offset with respect to the closed orbit
- Injected beam performs damped betatron oscillations about the closed orbit
- Bump closure can be a major issue (stable and reproducible kickers)

C. Bracco, B. Goddard, 4th TLEP workshop, 2013



Synchrotron injection

C. Bracco, B. Goddard, 4th TLEP workshop, 2013

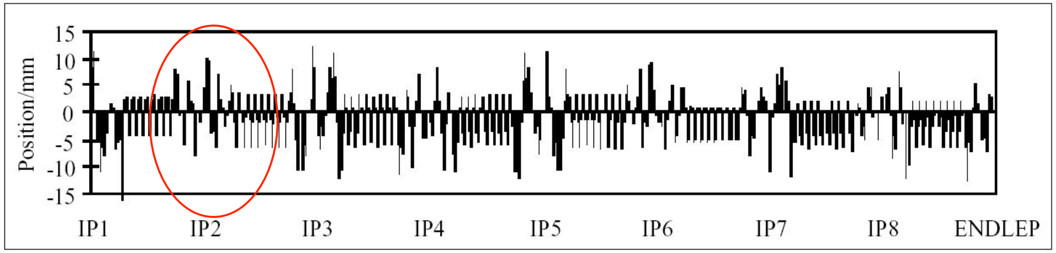


- Inject off-momentum
- Beam injected parallel to circulating beam, onto matched dispersion orbit of a particle having the same momentum offset $\Delta p/p_0$
- Injected beam makes damped synchrotron oscillations at synchrotron tune but does not perform betatron oscillations

Synchrotron injection at LEP

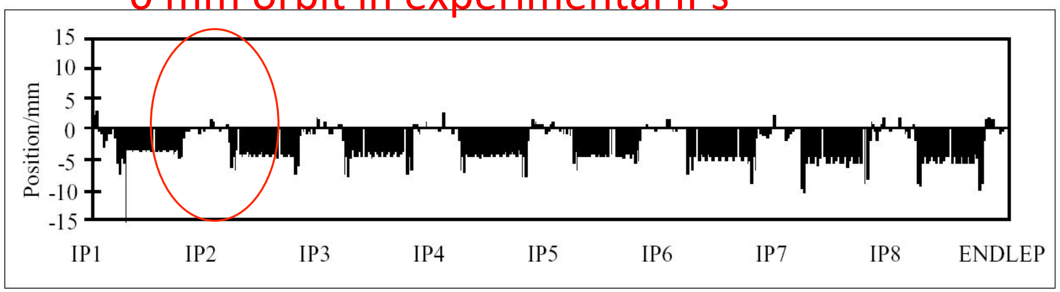
~10 mm orbit in experimental IPs

P. Collier, PAC 1995

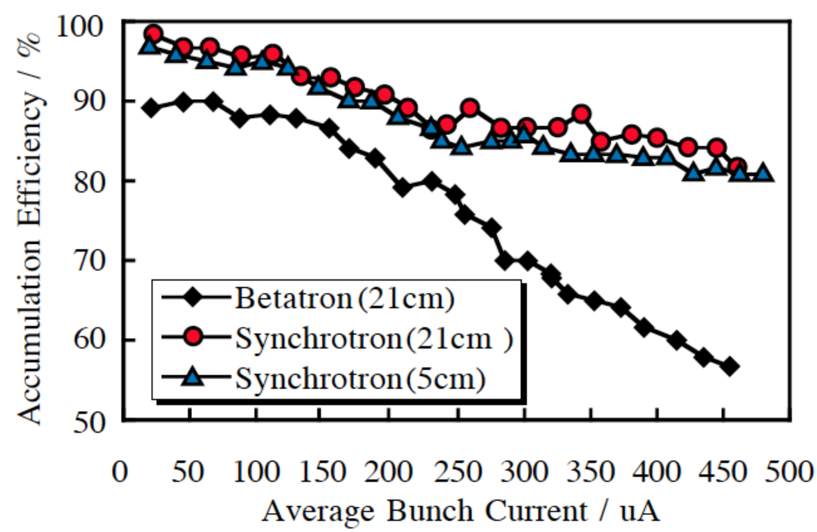


Optimized Horizontal First Turn Trajectory for Betatron Injection of Positrons into LEP.

~0 mm orbit in experimental IPs



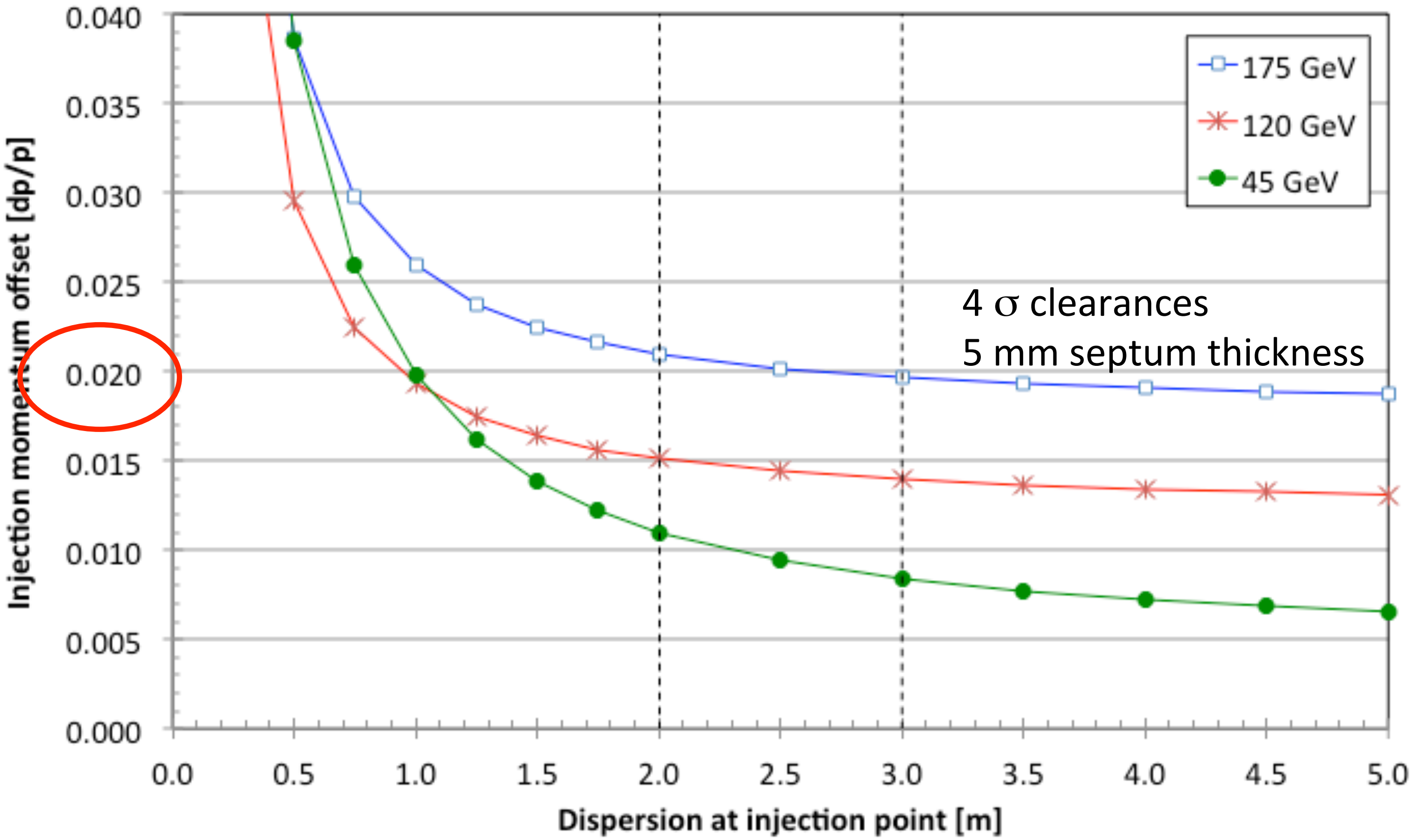
Optimized Horizontal First Turn Trajectory for Synchrotron Injection of Positrons with ΔP/P at -0.6%



- Synchrotron injection in LEP gave improved background for experiments due to small orbit offsets in zero dispersion straight sections
- It also improved greatly accumulation efficiency (85% for filled machine)

Dispersion vs momentum spread

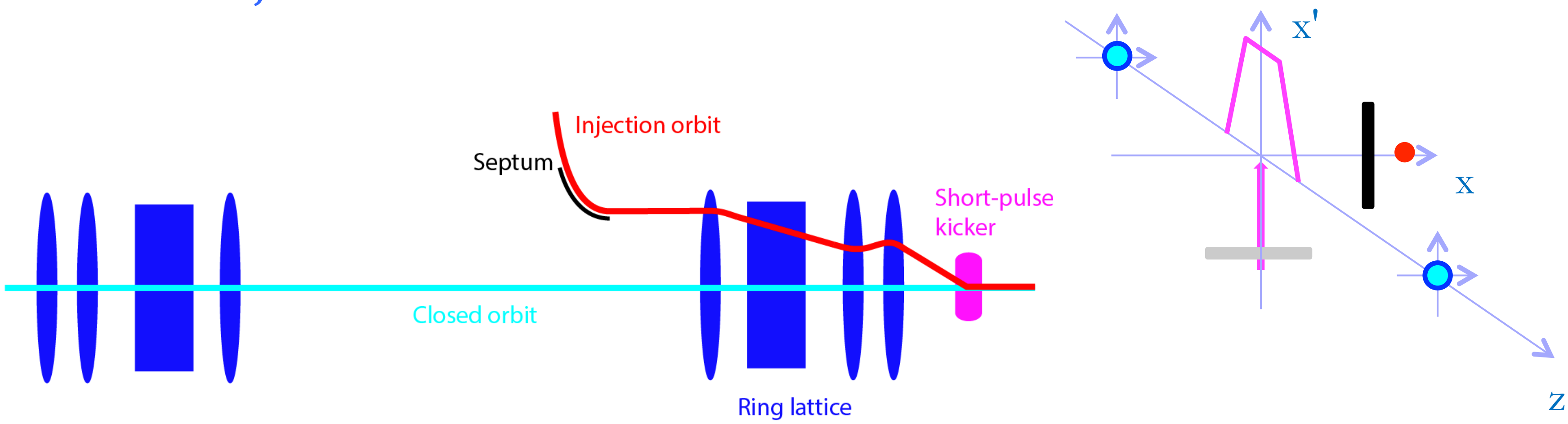
C. Bracco, B. Goddard, 4th TLEP workshop, 2013



- At 175 GeV would need to inject with 2% momentum offset
- Synchrotron injection gets difficult for higher energies due to momentum spread
- Marginal gain with larger dispersion

Longitudinal injection

M. Aiba, IPAC 2014

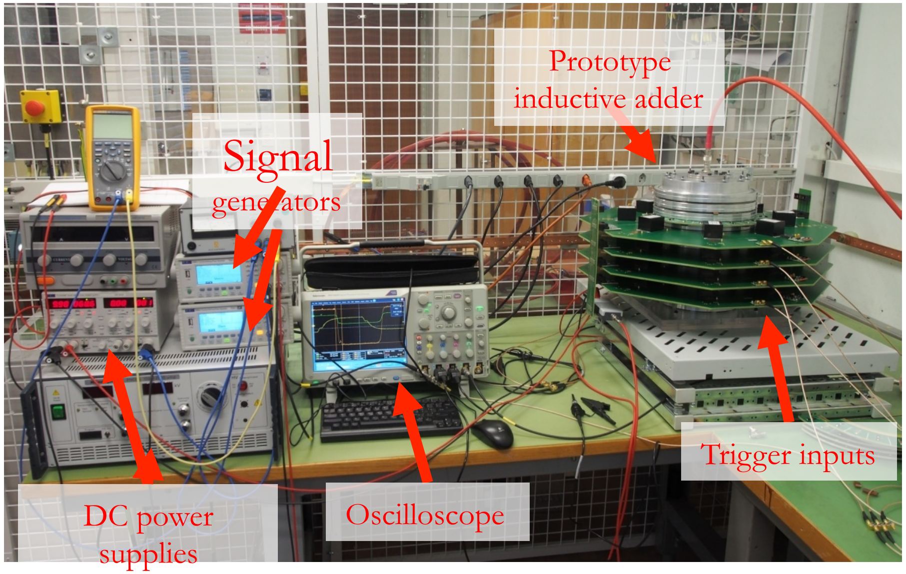


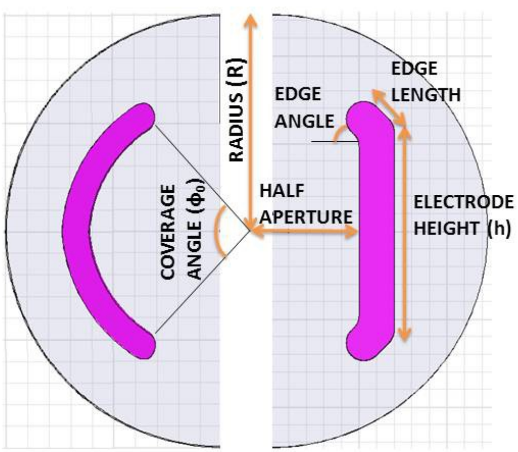
- Variant of synchrotron injection, by injecting bunches with a time off-set from circulating bunch
- Septum + Short-pulse (a few ns) dipole-kicker
  - On-axis injection
  - Transparent to circulating bunches
  - Without injection chicane

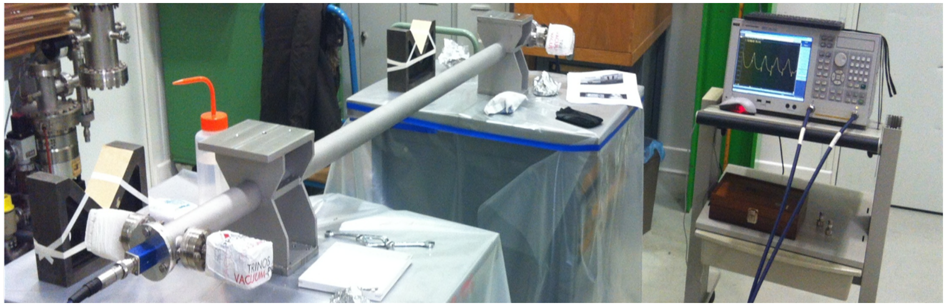
CLIC DR kicker

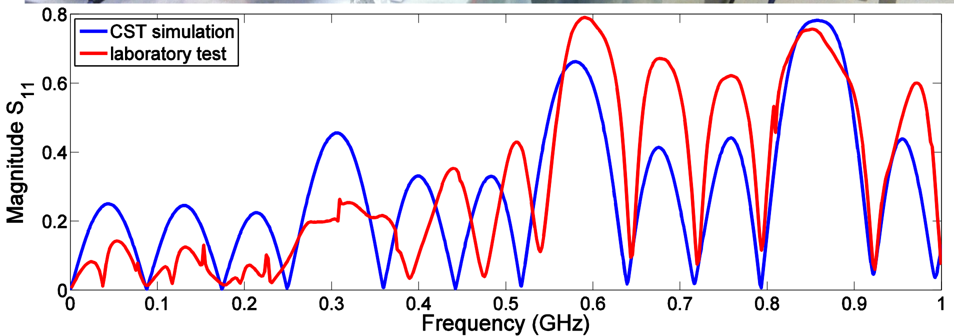
M. Barnes, J. Holma, C. Belver- Aguilar, A. Faus Golfe et al., CLIC workshop 2014

- Kicker jitter tolerance ~ few 10^{-4}
- Striplines required for achieving low longitudinal coupling impedance
  - Prototyped under the Spanish Program "Industry for Science"
  - Now, at CERN for laboratory tests
- Significant R&D done for pulser
  - First 5-layer inductive adder prototype under tests at CERN), second one to be assembled during this month
- Collaboration is set-up with ALBA synchrotron and ATF for beam tests



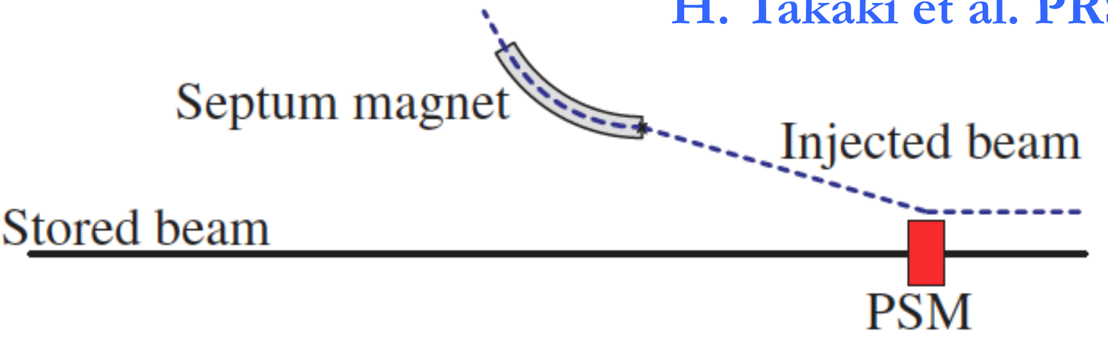


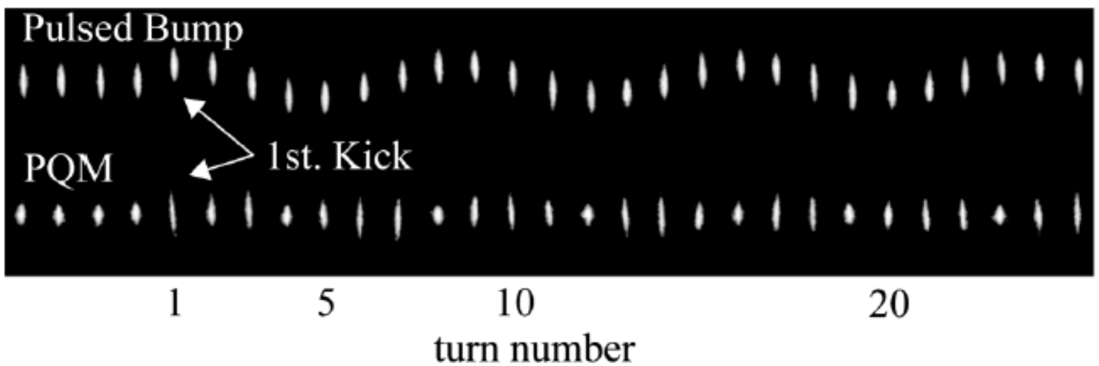




Pulsed sextupole injection

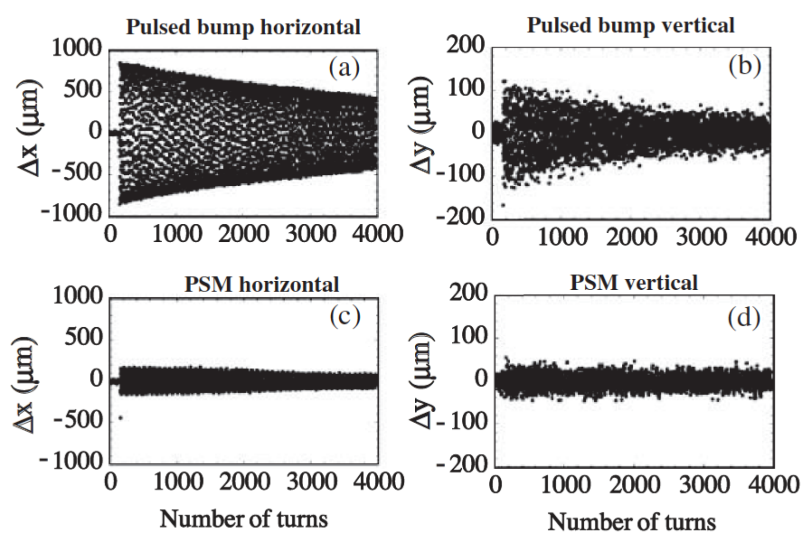
H. Takaki et al. PRSTAB 2010





- Using non-linear field for injecting while circulating beam remains unaffected
- Achieved stability of stored beam current <0.02%
- Coherent oscillations of stored beam greatly reduced
- Several light source upgrade projects consider it (MAXIV, Spring8,…)

Parameter	Value
Core length	300 mm
Bore diameter	66 mm
Number of coil turns	1
Integrated magnetic field at $x = 15$ mm	120 Gauss m
Peak current	3000 A
Inductance	4.3 μH
Pulse width	1.2 (2.4)[a] μs



Low Emittance Rings' Collaboration

- Common beam dynamics and technology issues for synchrotron light sources, linear collider damping rings and e+/e- colliders
- Formed a EU network within EUCARD2, started on 05/2013
  - Coordinated by CERN, INFN/LNF, JAI
  - Extended collaboration board including colleagues from US and Japan
  - 30 participating institutes world wide
  - First 4 network workshop with 60-80 participants @ Oxford (07/2013), Soleil (01/2014), Valencia (05/2014),
- Next low emittance rings' technology workshop on April 2015 at ALBA, Barcelona
- FCCee study should profit from it!

Outlook

- Flux requirements are very close to SuperKEKB and fully compatible with CLIC injector (using SPS as a damping ring)
- Ramp rate confortable (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 (D. Talman)
- Profit from low emittance rings collaboration and synergy with other projects at CERN (CLIC, LHeC,…) and abroad (SuperKEKB, X-ray storage rings,…)
- Polarization???

Lepton injector work units

J. Wenninger – FCC kick-off 2014

Lepton injectors
Overall design parameters
Baseline layout
Baseline parameters
Functional machine design
LEP chain performance and gaps
LEP chain compatibility with hadron injectors
New injector chain baseline
Technical systems
Low energy beam transfer lines
LIL/EPA re-installation feasibility
Existing injectors to be decommissioned for lepton operation
Technologies that require R&D
SuperKEKB-type injector option
CTF3 option usability
Planned LHeC test facility usability
Electron and positron sources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Thank you for your attention

Reserve Slides

SPS DR parameters

Parameter [Unit]	Lw=0m	Lw=2m	Lw=10m	Lw=2m	Lw=10m
Energy [GeV]	3.5	2.6	3.5	5	6.8
Hor. Norm. emit. [nm]	8800	**480**		5600	
Damping time (x,y) [sec]	9	1.46	**0.22**	0.64	**0.11**
Bunch length [mm]	**3.6**	11.5	3.7	20.5	32.5
Energy spread [%]	0.011	0.13	0.11	0.16	0.20
Energy loss/turn [MeV]	0.02	0.08	0.72	0.36	2.8
Bunches/pulse	<=4620				
Bunch spacing [ns]	5				
Repetition rate [Hz]	0.83				

- Need to revive lepton injector complex…