τ-Charm Injection System

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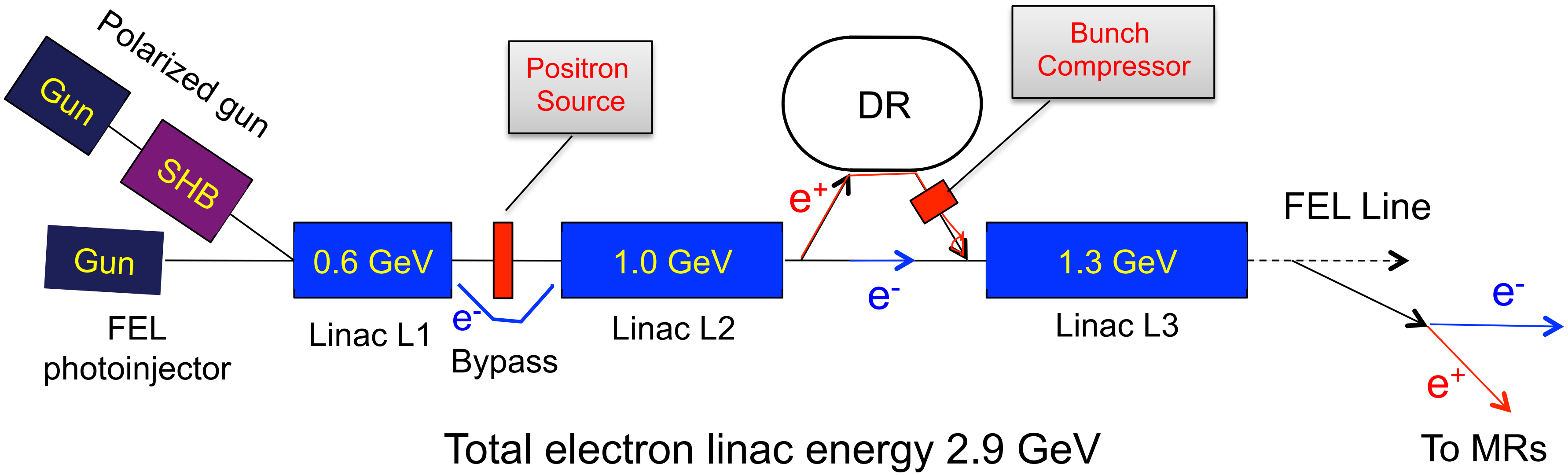
Workshop on Tau Charm at High Luminosity

La Biodola, Elba 29 May 2013

Injection system layout

- The preliminary layout of the injection system is based on the design of the SuperB injection system
- The same design for the linac and damping ring lattice is used
- The main difference with respect to the SuperB design is the fact that only positrons are stored in the Damping Ring (DR)
- Also for the Tau Charm the linac can be used to accelerate electron pulses for an FEL synchrotron light source

Tau-Charm Injection System



Total electron linac energy 2.9 GeV
Total positron linac energy 2.3 GeV

	Linac L1	Linac L2	Linac L3
N. of klystrons	3	6	7
N. of cavities	9	18	21
Max. Energy (GeV)	0.62	1.24	1.45

The number of klystrons and cavities allows to reach the maximum positron energy of 2.3 GeV also with one klystron off

Tau-Charm Injection System

Linacs L1, L2 and L3 have same parameters as in SuperB, only the number of sections and klystrons is changed, since they scale with the respective energies

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Total positron linac energy 2.3 GeV

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τ-Charm Main Rings
Preliminary parameters relevant for injection

	e^-	e^+
Max. Energy (GeV)	2.3	2.3
Number of bunches (C = 330 m)	513	513
Particles/bunch N @ L=2e35 $cm^{-2}s^{-1}$	3.7×10^{10}	3.7×10^{10}
Charge/bunch (nC)	6.0	6.0
Horizontal emittance (nm)	5.5	5.5
Vertical emittance (pm)	14	14
Lifetime τ (sec)	≥ 300	≥ 300
Injected beam polarization	≥80%	0
Particles lost/beam/sec	$\sim 6 \times 10^{10}$	$\sim 6 \times 10^{10}$

For SuperB the number of particles lost/beam/sec is
2×10^{11} for e^+ and 4×10^{11} for e^-
a factor 3 ÷ 7 higher than τ-Charm

Injection Rates

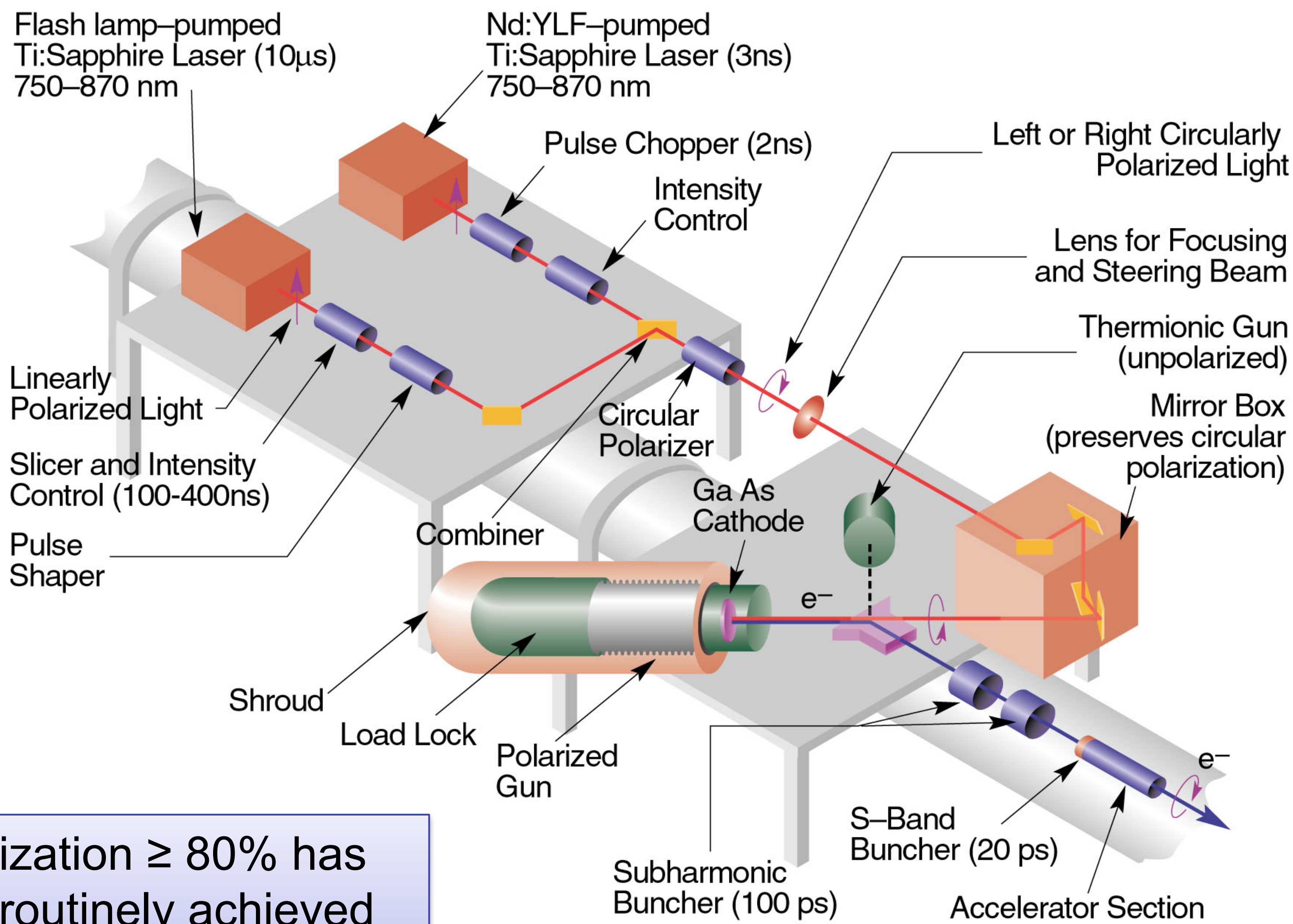
- Assuming:
  - **25** Hz continuous injection in each ring
  - 4 bunches /pulse
- Each one of the 513 bunches will be refilled after

  $\Delta t = 563/4/25 = 5.1$ s,
- with a number of particles $\Delta N \cong N \cdot \Delta t / \tau$
- Since the luminosity is proportional to the square of the bunch current the average luminosity loss with respect to the peak value will be $\Delta L / L_{peak} \cong 2\langle \Delta N / N \rangle = 2(\Delta N / N)/2 \cong \Delta t / \tau$

	e^-	e^+
N particles/bunch @ L=2e35 $cm^{-2}s^{-1}$	3.7×10^{10}	3.7×10^{10}
Particles lost/beam/sec	6×10^{10}	6×10^{10}
ΔN injected/bunch/pulse	6.3×10^{8}	6.3×10^{8}
Required injected charge/bunch/pulse (pC)	100	100
MAX injected charge/bunch/pulse (pC)*	200	200
$\Delta L/L_{peak}$ %	1.7	

*Required to fill the beam from scratch and kept as a safety margin

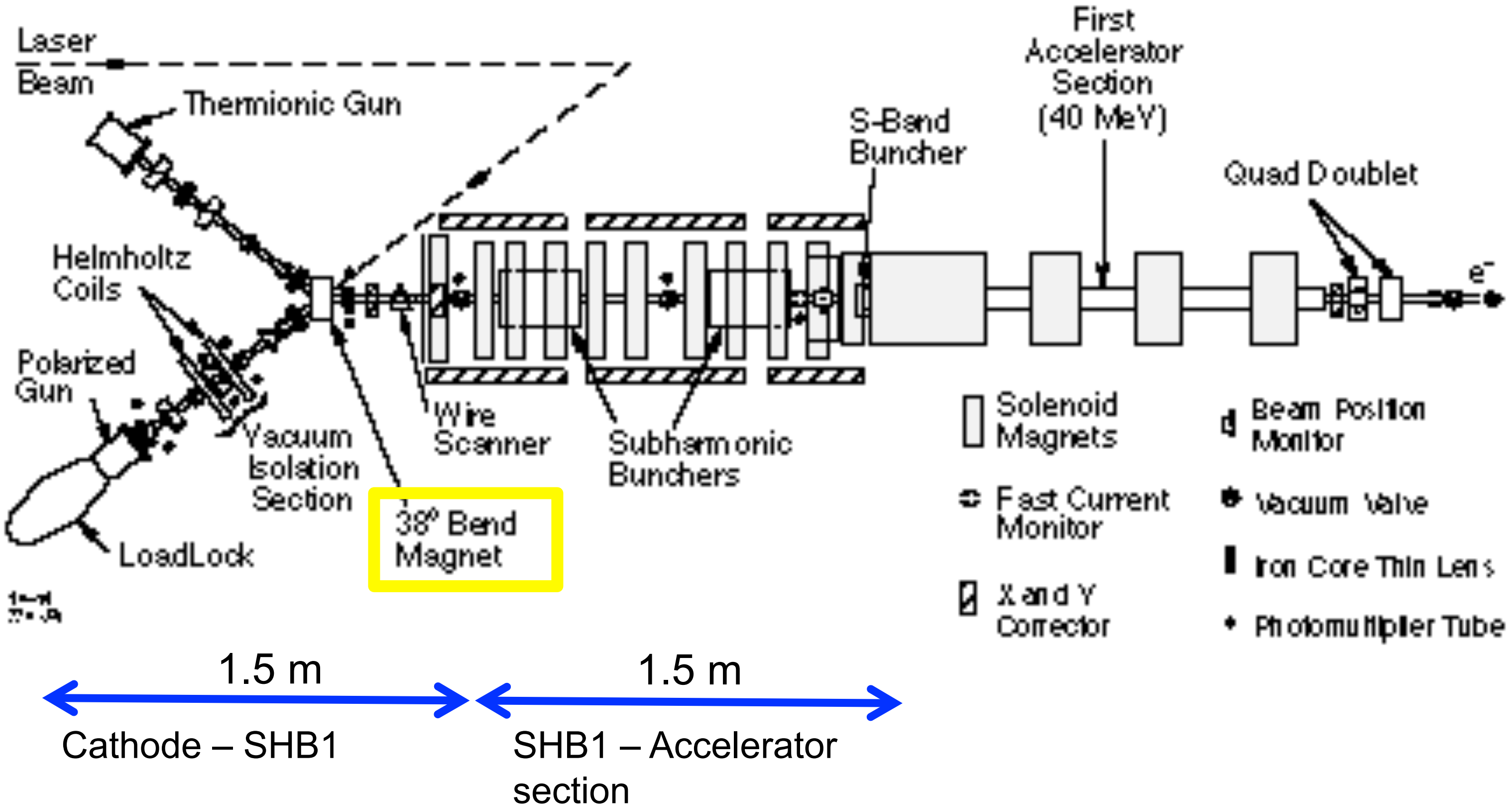
SLC Polarized gun



Polarization ≥ 80% has been routinely achieved
Measured up to …

NIMA 365 (1995)

SLC Polarized gun



Electrons without Damping Ring

- Due to the low charge per bunch needed a low electron emittance might be obtained directly from the polarized gun, without a DR
- Two different solutions are under study:
  - The one proposed from Bacci, Rossi for SuperB (see slides)
  - Just cutting the vertical beam size at the exit of polarized gun + buncher: *a charge reduction less than a factor 10 should give the required emittance*

SuperB, electron Source Proposal
A.Bacci - A.R.Rossi

Electrons without Damping Ring
SuperB Project
December 2011

Tracking of one bunch:
@ GaAs Cathode - Laser 860 nm
Q= 160 pC ; Sig_X_laser=1.27 mm; Flat-top = 20 psec; Thermal_emit,n=0.415 mm-rad

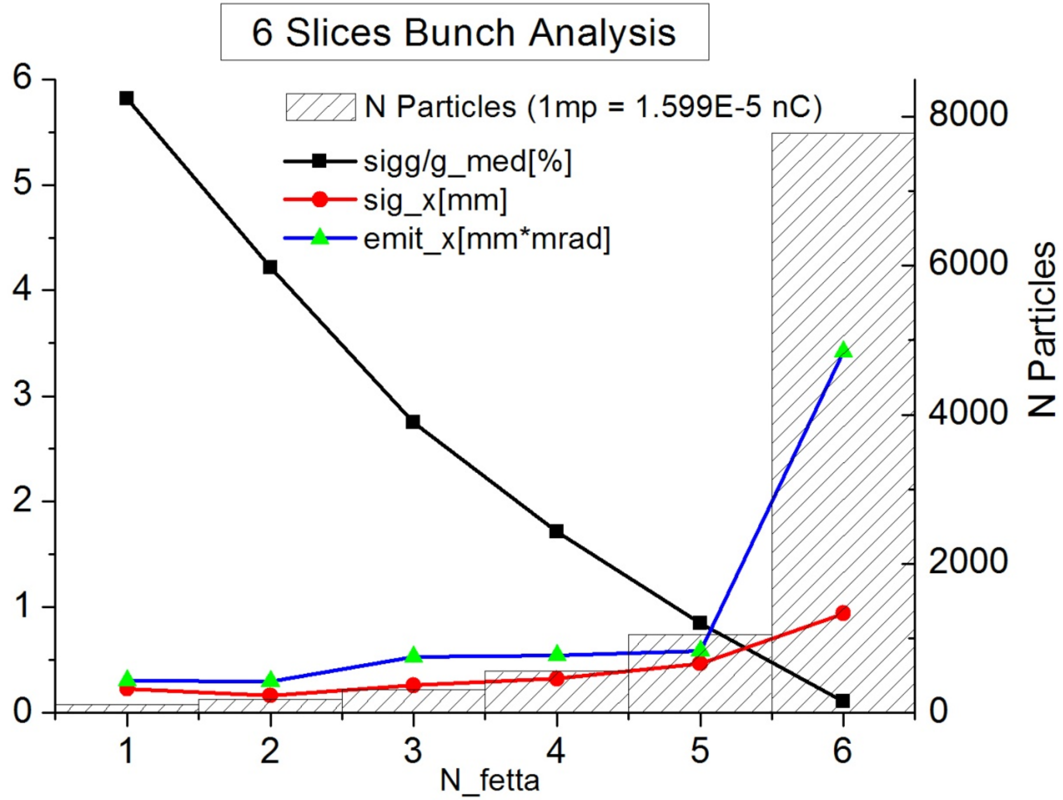
Very preliminary layout:
-DC gun (Jlab type) Energy exit at 100keV

- I SubHBuncher&boost (Ep=3.4MV/m), Energy exit at 560 keV
- II SubHBuncher&boost (Ep=3.4MV/m), Energy exit at 890 keV
- L-Band cavity SW Pitz type (VBunching) (Ep=8MV/m), Energy exit at 6.2 MeV
- S-Band cavity (ligth VB and Boost, Ep=14.2 MV/m), Energy exit at 37 MeV

-64 S-Band cavity, ~25MeV/m from 37 MeV up to 4.23 GeV

- X-band TW cavity (120 Cells ~ 1 m length), E_spread correction, Energy exit at 4.183MeV

Bunch at Linac Exit – Slice analysis

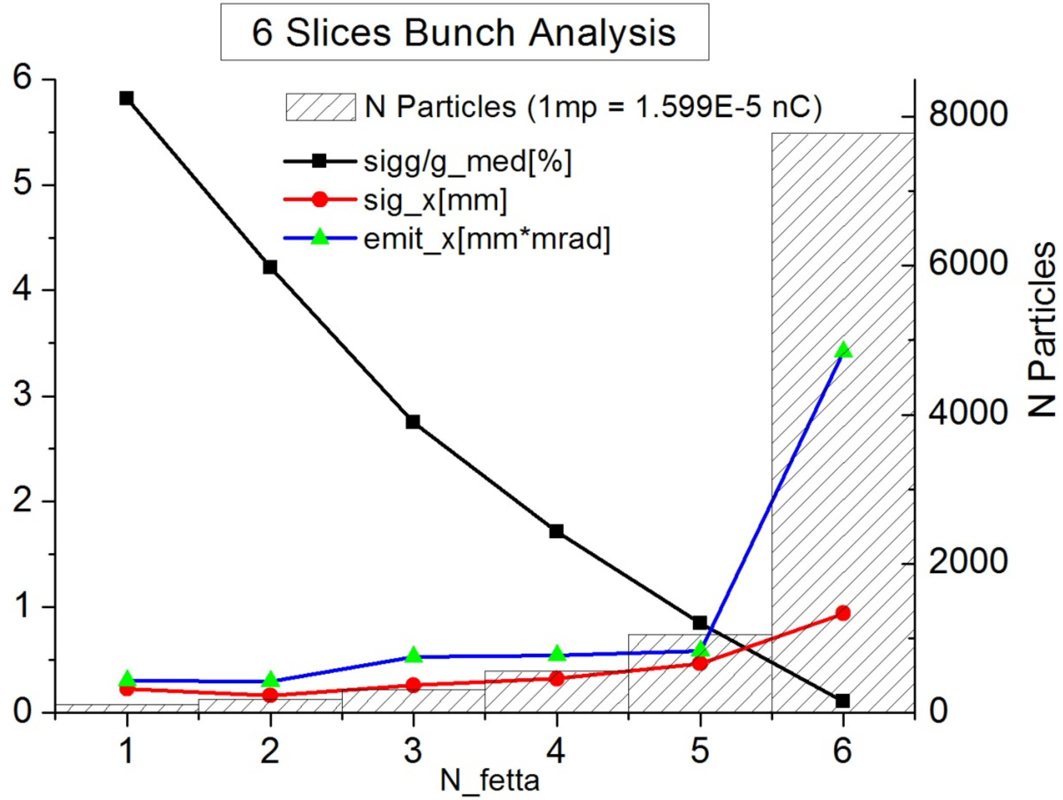


Slice N. 6
80% of the charge
Q = 125 pC
Normalized emittance
$\varepsilon_x = \varepsilon_y = 3.4$ mm mrad
Relative energy spread
$\sigma_\gamma/\gamma = 1.1\text{e-}3$

Requirements
5 bunches, Q = 130 pC
Normalized emittances
$\varepsilon_x = 45$ mm mrad
$\varepsilon_y = 6$ mm mrad
Relative energy spread
$\sigma_\gamma/\gamma = 1.3\text{e-}3$

X-band @ linac exit:
On $\sigma_\gamma/\gamma = 1.06\text{e-}3$ (Energy variation from 4.24 to 4.18 GeV)
Off $\sigma_\gamma/\gamma = 1.40\text{e-}3$ (Energy 4.18 GeV)

Bunch at Linac Exit – Slice analysis



Slice N. 6
80% of the charge
Q = 125 pC
E = 4.2 GeV
Normalized emittance
$\varepsilon_x = \varepsilon_y = 3.4$ mm mrad
Relative energy spread
σ_γ/γ = 1.1e-3

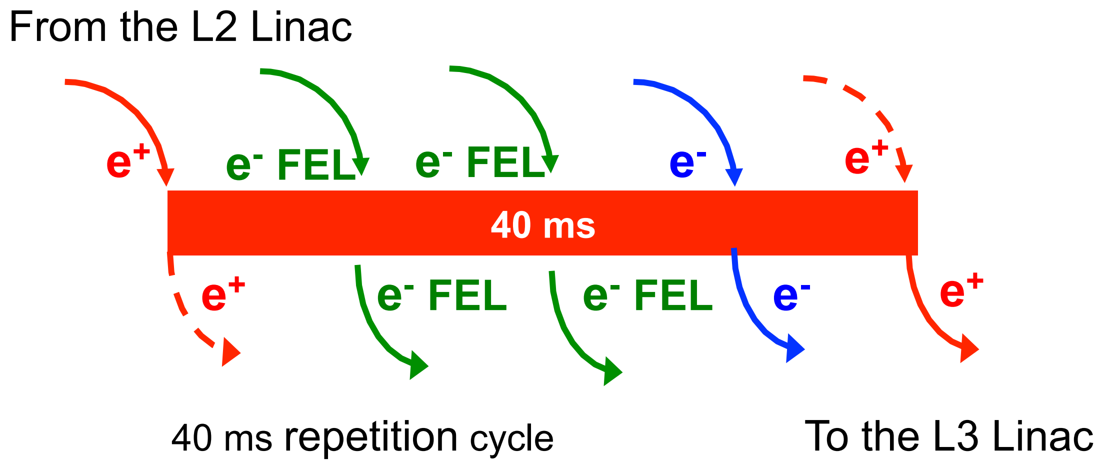
Tau-charm Requirements
E = 2 GeV
4 bunches, Q ≤ 200 pC
Normalized emittances
$\varepsilon_x = 52$ mm mrad
$\varepsilon_y = 5$ mm mrad
Relative energy spread
σ_γ/γ = 1.5e-3

X-band @ linac exit:
On σ_γ/γ = 1.06e-3 (Energy variation from 4.24 to 4.18 GeV)
Off σ_γ/γ = 1.40e-3 (Energy 4.18 GeV)

Timing scheme of the beams accelerated in the Linacs

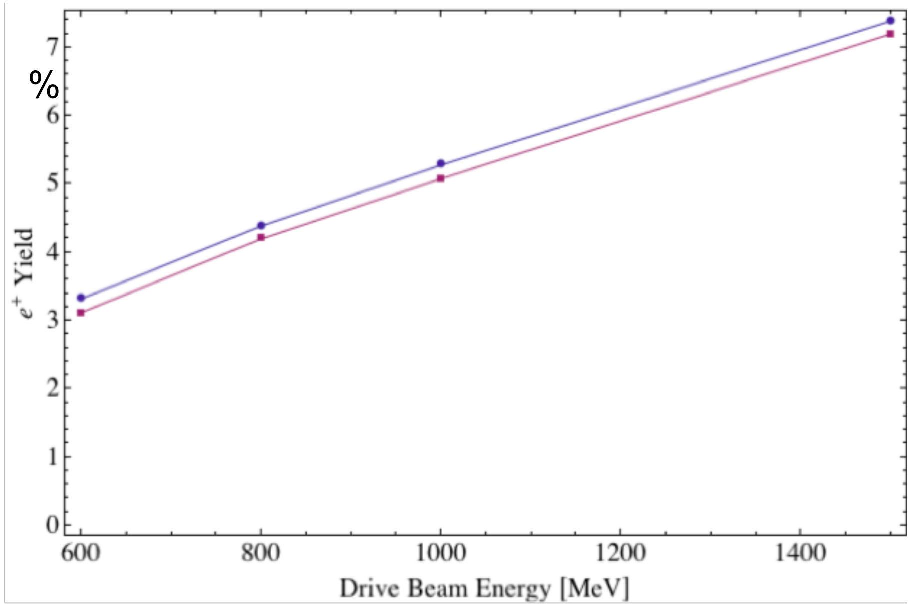
- e^- are not stored in DR
- e^+ store time in DR 40 ms
- 2 FEL pulses during e^+ store time
- Repetition cycle 40 ms
- Effective injection frequency per ring 25 Hz
- Effective FEL frequency 50 Hz

Only positrons are stored in the damping ring for 40 ms



Positron Production

Tungsten target, Adiabatic Matching Device, Solenoidal field, S-band capture and accelerating sections



Yield of positrons within the longitudinal and transverse DR acceptance as a function of the drive beam energy for a FODO cell (red) and FDOFDO cell linac

T. Demma, IPAC12

Electron drive beam

We assume to have 10 nC/bunch from the gun and a bunching efficiency of ~90%

Injection requirement
200 pC per bunch
Yield 2%

Choice of the conversion energy
0.6 GeV
Yield 3%

Positron DR Parameters

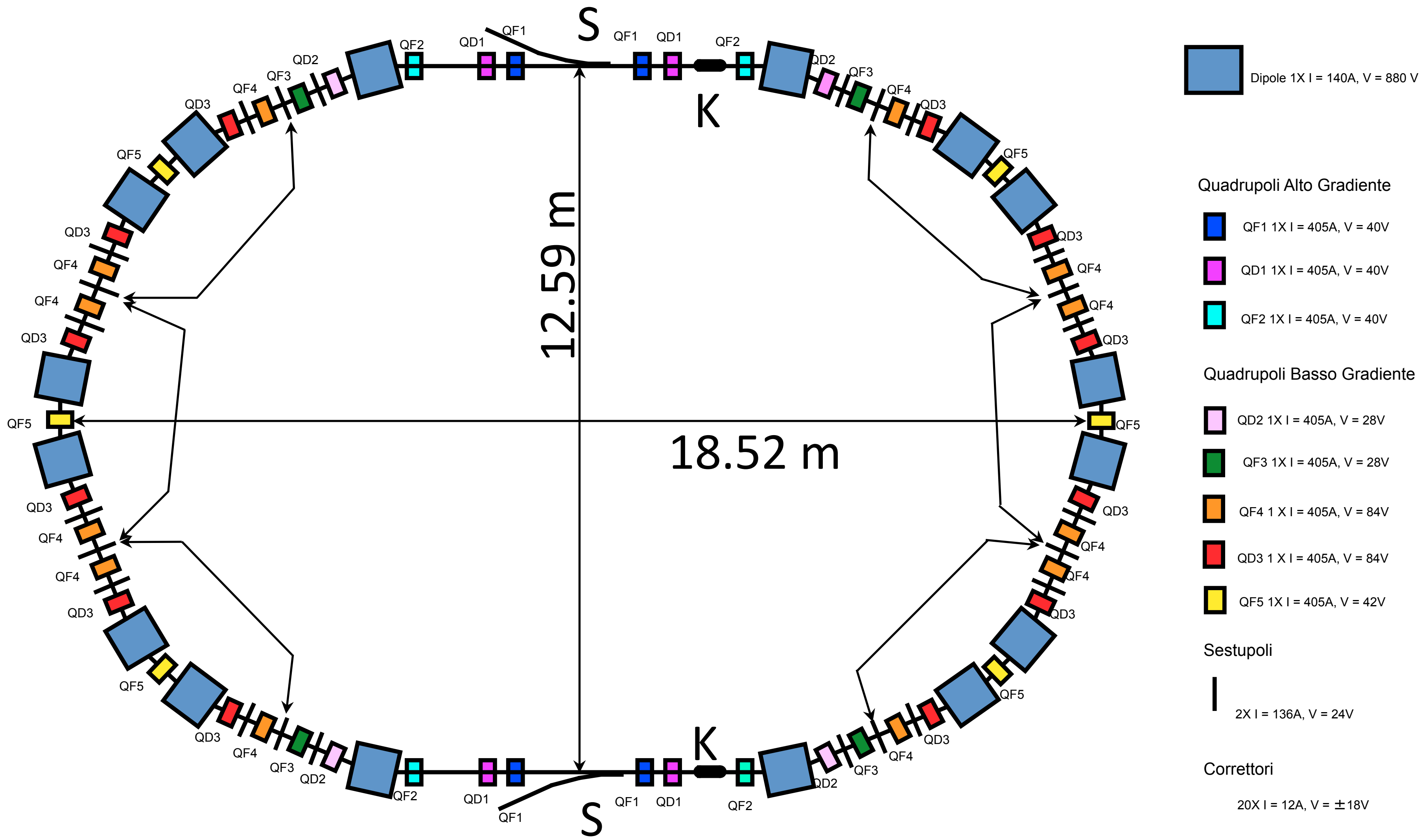
Energy (GeV)	1
Circumference (m)	59.2
Hor. Betatron tune	7.41
Ver. Betatron tune	2.41
Horizontal chromaticity	-11.6
Vertical chromaticity	-9.3
Horizontal emittance (nm rad)	24
Momentum compaction	0.0052
H/V damping time (ms)	8.8
Syn. Damping time (ms)	4.4
Relative energy spread	6.10E-04
RF frequency (MHz)	476
Harmonic number	94
RF peak voltage (MV)	0.56
Bunch length (mm)	4.5

DR design is the same as the SuperB one with minor modifications:

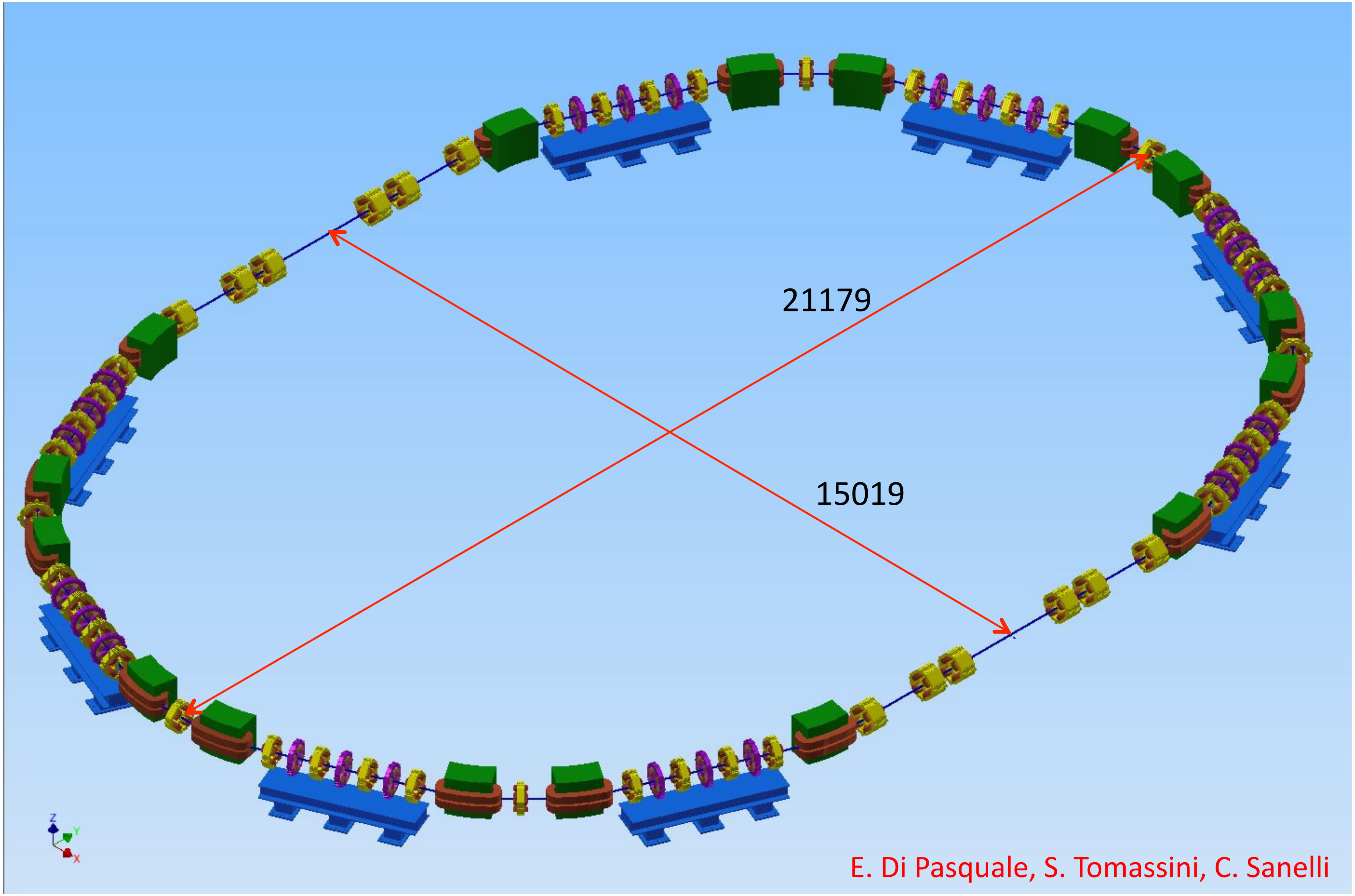
- energy has been lowered from 1.1 GeV to 1.0 GeV
- dipole field has been reduced from 1.9 to 1.7 T to reduce power consumption

As a result the damping time is increased from 6.6 ms to 8.8 ms, which is fine with the present store time of 40 ms (was 20ms for SuperB)

Positron DR Layout



Positron DR Mechanical layout



Transfer lines

- The transfer lines design can be based on SuperB one
- TLs between DR and linac can be simplified with the present layout (no DR for the electrons, all the linac on the same line)
- TLs from linac to Main Rings: design similar to SuperB, magnetic fields scaled with the energy
- The parameters for the bunch compressor after the DR (only for positrons) have to be reevaluated

Positron Ring Injection Parameters

	PR
Septum thickness Δs (mm)	3
β_{xs} (m) @ septum	90
β_{xi} (m) @ injection line	40
β_{xk} (m) @ kicker	30
Injected emittance ε_{xi} (m rad)	1.3E-08
Stored emittance ε_{xs} (m rad)	6.0E-09
Stored σ_x (m)	7.3E-04
Injected σ_x (m)	7.1E-04
$xmax_{inj}/\sigma_x$	13.9
$xmax_{inj}$ (m)	1.02E-02
bsc/sx	20
θ kick (mrad)	0.23

Assumptions:

The ring transverse acceptance is $20\sigma_x$

The injected beam energy spread is well within the ring energy acceptance

Next Steps

- Electrons without Damping Ring
  - The two solutions will be studied to get more confidence on the parameters achievable at the ring injection
- Modifications of the transfer lines
- Evaluation of the beam energy spread at the end of the linac and the parameters of the bunch compressor
  - In alternative: evaluate the feasibility of a second harmonic RF cavity to reduce the bunch length by a factor 2
- Detailed study of the MRs injection based on the final lattice design