SuperB Accelerator

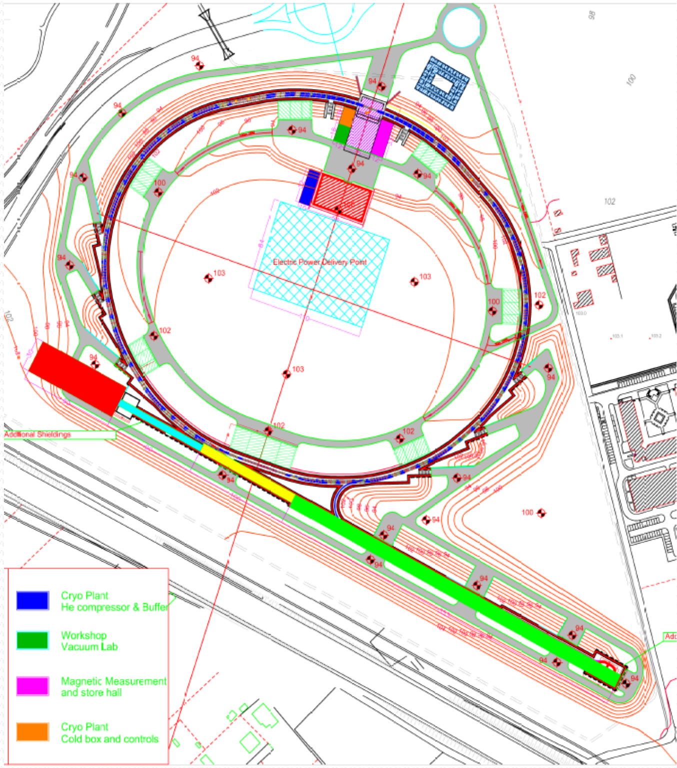
M. Biagini, LFF Workshop, Napoli 22-23/11/12

SuperB project

- High luminosity B-Factory → **10^{36} cm^{-2}s^{-1}**
- 2 rings: HER(e^+) @6.7 GeV, LER(e^-) @4.18 GeV
- Collision scheme: Large Piwinski Angle & Crab Waist sextupoles (LPA&CW) → large crossing angle, small beam sizes, very small emittances, $\beta_y^* << \sigma_l$
- Twin SC IP doublets of «new» design
- Low emittances comparable to latest generation SL sources and Damping Rings
- Unique feature: polarization of e^- beam in LER
- Possibility to use Linac for SASE-FEL in parassitic mode
- Site: Tor Vergata University campus (5 Km from LNF)
- Consortium «Nicola Cabibbo Laboratory» in charge

SuperB progresses

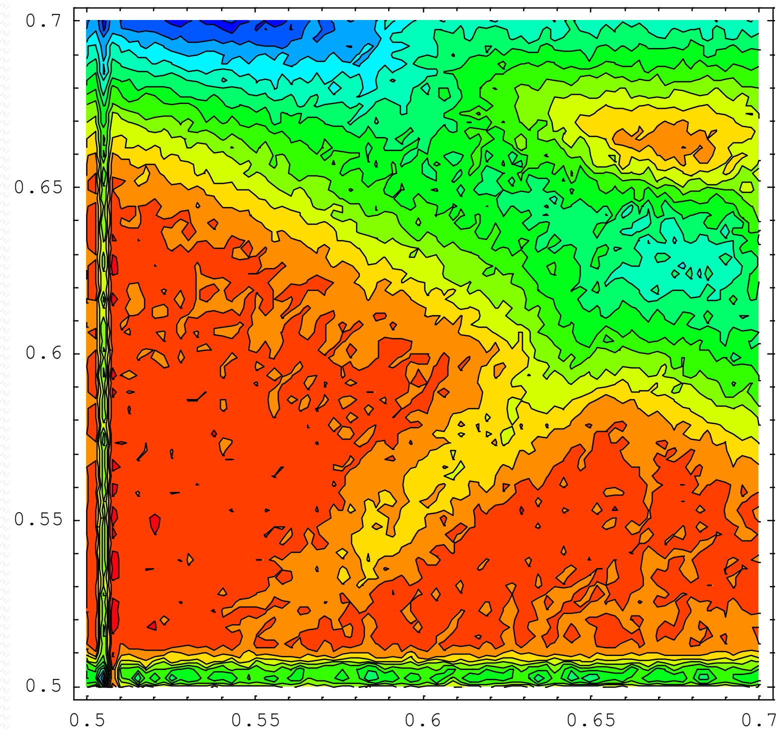
- Layout optimized to fit Tor Vergata site, ground motion measurements showed that vibrations are very well absorbed
- LER dipoles changed to increase polarization degree to 80%, Final Focus geometry changed for better spin dynamics
- Coupling correction with and without detector solenoid implemented
- Beam pipe radius increased, evaluation of beam power ready for final vacuum design
- Injection system optimized to incorporate SASE-FEL option
- Lattice ready for engineering stage
- Costs review done



SuperB parameters

- Low emittances tuning procedure developed and tested at DIAMOND and SLS
- Beam currents similar to previous B-factories but Luminosity 100 times larger
- BB simulations show large operational area in tune space
- Flexibility to achieve the design Luminosity with different beam parameters

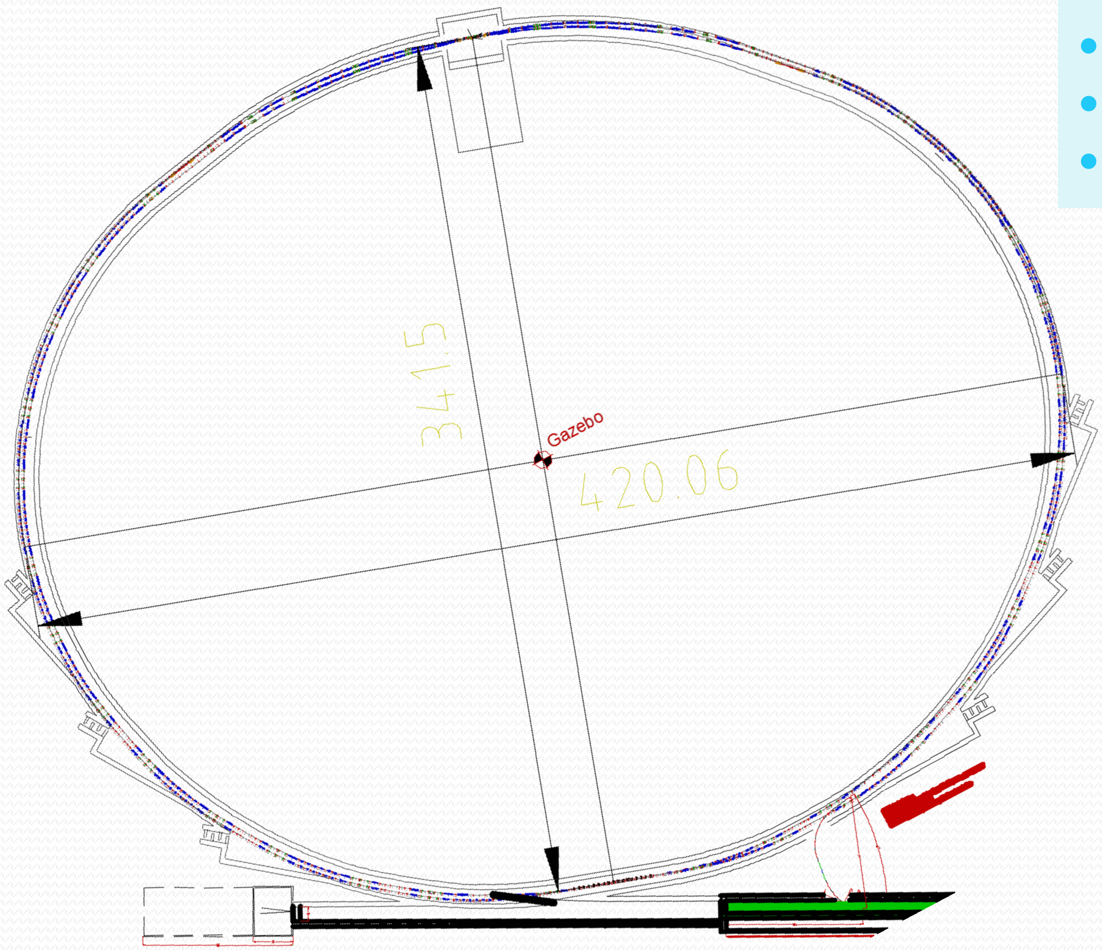
Parameter	HER (e^+)	LER (e^-)
Luminosity ($cm^{-2}s^{-1}$)	10^{36}	
E (GeV)	6.7	4.18
C (m)	1205	
Crossing angle (mrad)	60	
Piwinski angle	19.6	17. 5
BB tune shift (x/y)	0.0026/0.11	0.004/0.105
N. bunches	937	
I (mA)	1976	2446
Part/bunch ($x10^{10}$)	5.30	6.56
IP $\beta_{x/y}$ (cm/mm)	2.6/0.253	3.2/0.205
$\varepsilon_{x/y}$ (nm/pm) (with IBS)	2.26/5.7	2.29/5.7
IP $\sigma_{x/y}$ (μm/nm)	7.7/38	8.6/34
σ_l (mm)	5	5
Polarization (%)	0	80



Main focus 2012

- Site constraint at Tor Vergata required modifications to the injection sections. A realistic lattice and footprint was produced to integrate the required equipment (diagnostics, correctors, kickers, etc…)
- Polarization of LER electron beam
  - in lattice V16, fitting the Tor Vergata site and decreasing the beam emittance to fight IBS, shorter dipoles resulted in a shorter depolarization time and a lower polarization degree (close to 70%)
  - to restore it to 80% the dipole curvature in LER was reduced by 1.5 → depolarization time has been increased
- Cost estimate. Choice to use as much as possible well assessed technology and market available hardware
- SASE X-FEL integration

Present MR layout



HER and LER similar lattice:

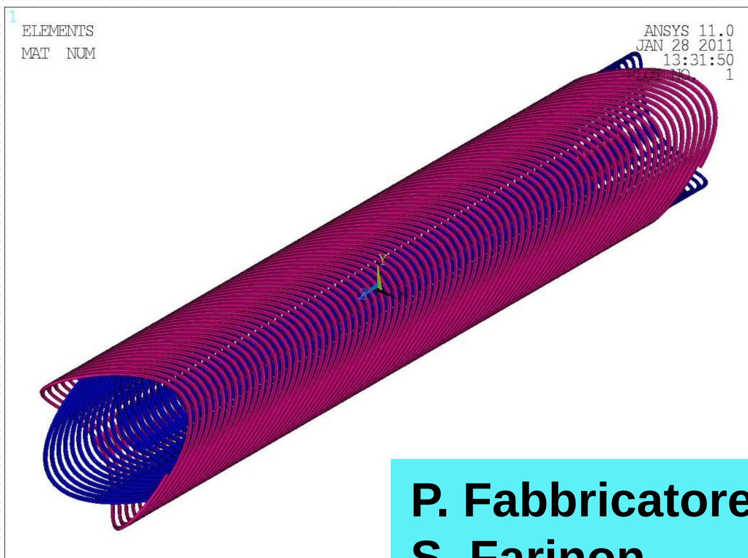
- Arc cells
- FF and IR
- High beta injection section
- RF and utilities straight section

- Injection section was moved for better TL layout
- Final Focus geometry was changed to have better spin dynamics
- FF coupling correction with and without detector solenoid was implemented

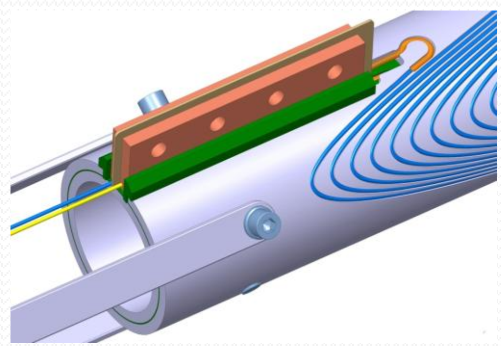
P. Raimondi
S. Sinyatkin
M. Biagini

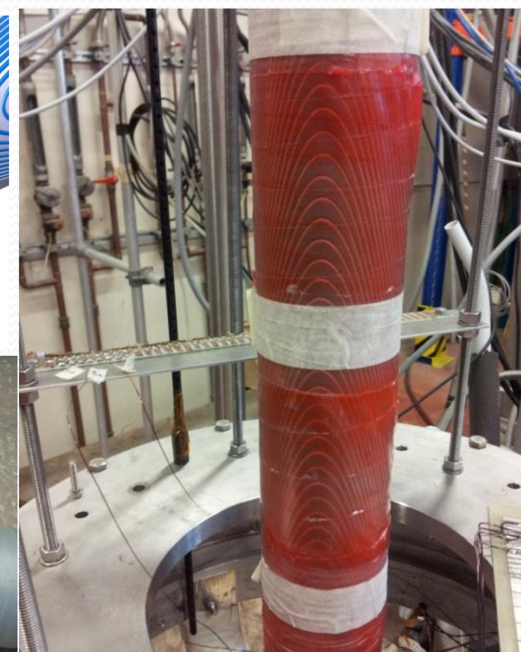
IP Doublets

- The low space allowed to FF doublets required the development of innovative magnets
- Helical coil technology. Two-layer winding concept (talk by Paoloni)
- High Current density (2 kA/mm^2 in the wire) → Potential quench issues (protected)
- A model coil, designed by INFN, has been constructed at ASG Superconductors and tested at INFN Genova



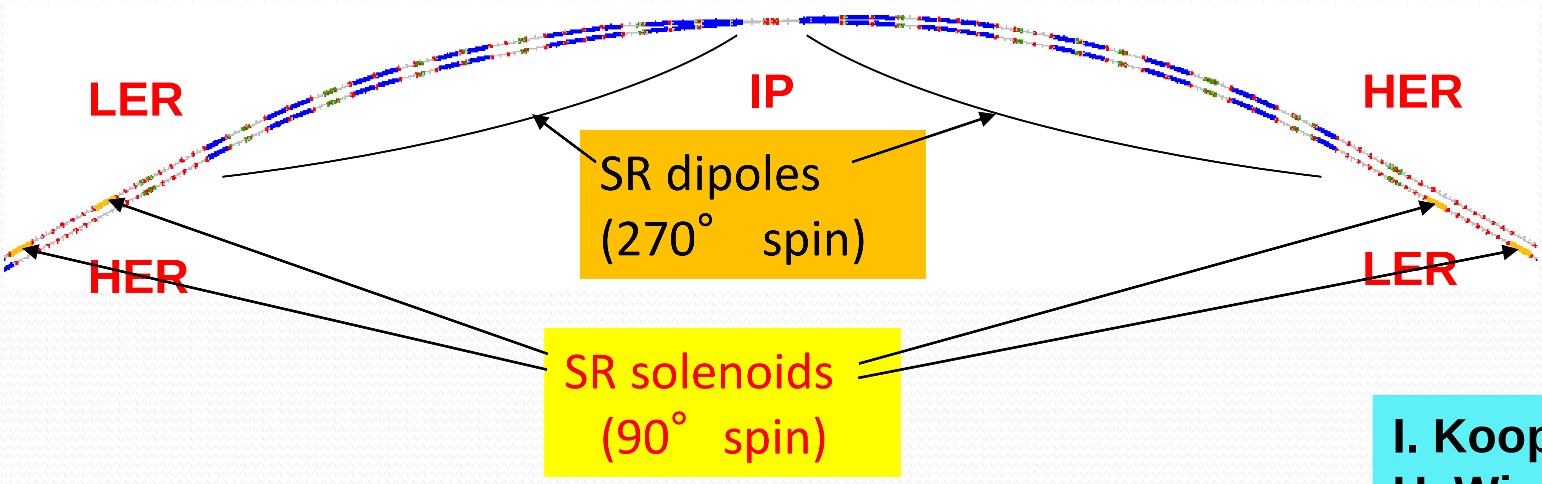
P. Fabbricatore
S. Farinon
R. Musenich
E. Paoloni





Polarization

- Longitudinal polarization of e^- at IP in the LER unique SuperB feature
- 80% polarization degree desirable, assuming 90% from polarized gun (ex. SLAC) and 3.5 minutes beam-beam lifetime
- Beam polarization resonances do constrain the beam energy choice
- Spin rotation at IP from 90° in x → 90° in z & 90° in y → constraints on the FF bending angles of LER and HER in order to achieve the right spin dynamics
- Solenoids are split & decoupling optics (7 quadrupoles) added



I. Koop
U. Wienands

MR Magnets design

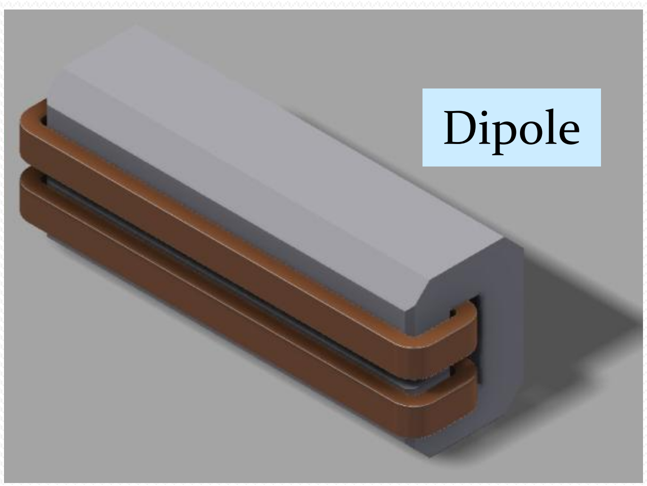
I. Okunev

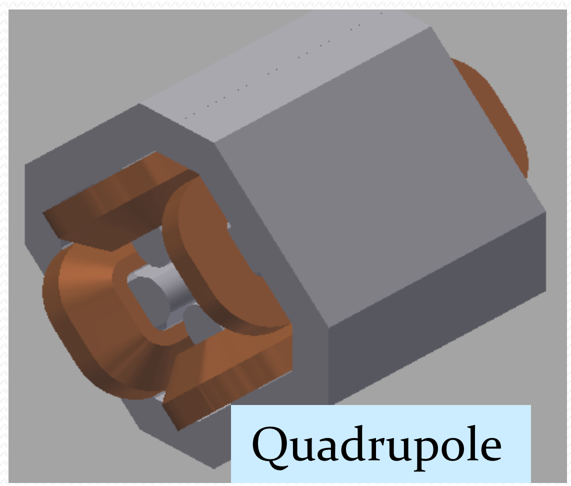
HER Dipoles (Bro_HER= 22.35 T*m)

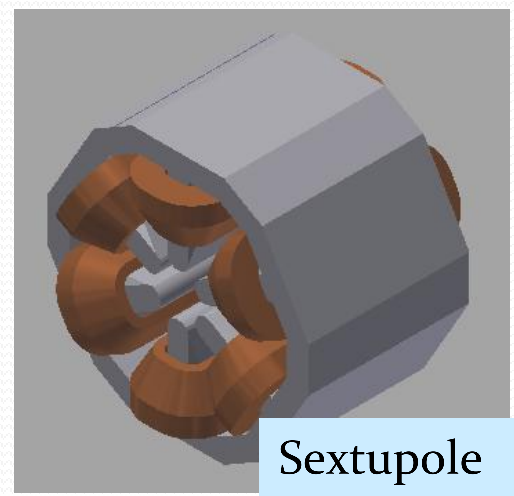
Magnet length, m	1,48	2,8	3,65	4	4,1	4,27	4,7	TOTAL
Number of magnets	102	2	8	4	26	12	40	194
Max field, T	0,295	0,099	0,3	0,274	0,319	0,257	0,295	
Radius, m	75,76	225,75	74,50	81,56	70,06	86,96	75,76	

LER Dipoles (Bro_LER= 13,94298 T*m)

Magnet length, m	0,7	1,2	2,8	3,65	4,1	TOTAL
Number of magnets	110	108	2	8	24	252
Max field, T	0,488	0,36	0,049	0,181	0,181	
Radius, m	45,80	62,08	456,10	123,47	123,47	



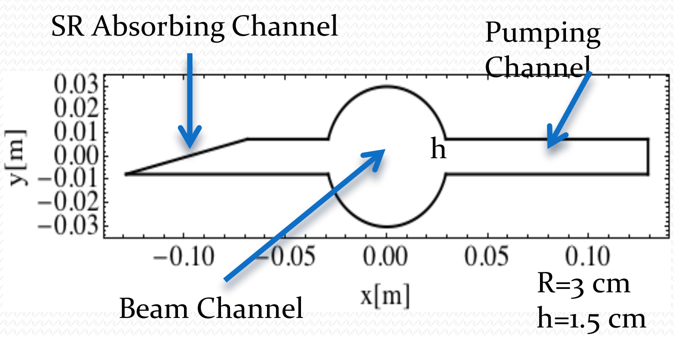




T. Demma

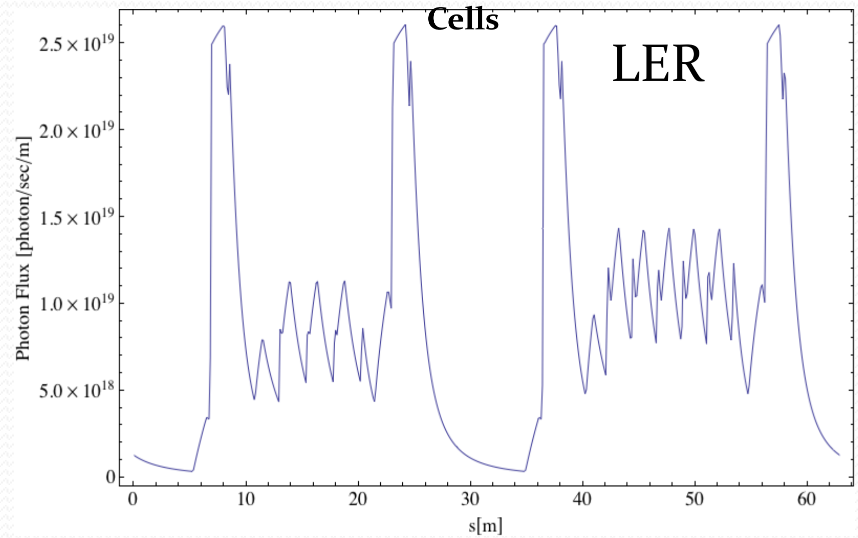
Synchrotron Radiation distribution in Arc-cells

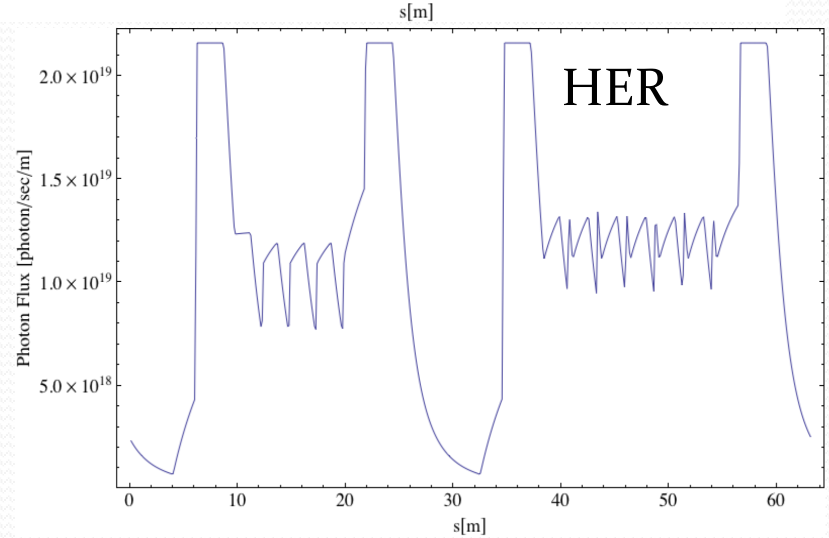
Beam Chamber Cross Section



Slanted (1/4 aspect ratio) antechamber to increase the SR absorbing surface.

Photons/sec/m hitting chamber wall in Arc-Cells





Synchrotron Radiation Flux on Chamber Walls

	SuperB LER	SuperB HER	S-KEKB LER*	S-KEKB HER*
$\Gamma_{max}[o^{19}ph/s/m]$	2.6	2.2		
$\Gamma_{av.}[10^{19}ph/s/m]$	1.0	1.2	0.5	0.7
$P_{max}[W/mm^2]$	2.4	4.9	2.3	17
$P_{av.}[W/mm^2]$	0.5	2.1		

* Suetsugu et al., JVST-A, 30 (3), 2012

SuperB

CABIBBO LAB
Laboratorio Nicola Cabibbo

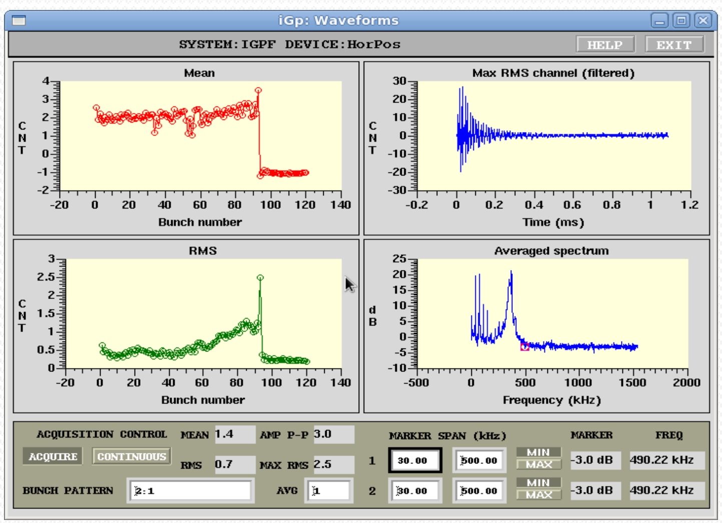
MR Collective Effects

T. Demma

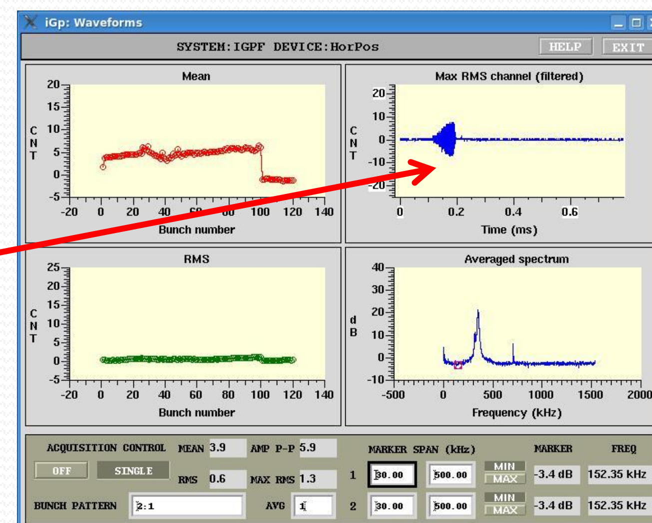
- Electron Cloud instability in HER:
  - Extensive simulations show that a peak Secondary Electron Yield (SEY) of 1.1 and 99% antechamber protection result in a cloud density just below the single-bunch instability threshold. Countermeasures:
    - antechambers to reduce SR inside the beam pipe, TiN coatings (peak SEY ~1)
    - solenoids in the drifts
    - grooves in the dipoles chamber (where solenoids are not effective) to further reduce effective secondary electron emission
  - Work in progress: primary photoelectrons distribution along the ring is under study using the newly developed 3D photon-tracking simulation code Synrad3D. Both instability threshold and e-cloud density evolutions are being estimated in view of the variation of the lattice, beam and pipe parameters
- Fast Ion Instability in LER:
  - Multi-particle tracking simulations in different bunch filling patterns with bunch-by-bunch feedback system, assuming conservative values of the initial CO Partial Pressure (3×10^{-8} Pa) and of the feedback damping time (50 turns)
  - Results show that the instability is suppressed by the feedback system when 40 ns gaps (10 bunches) are introduced in the filling pattern every 100 bunches, while this is not the case for shorter gaps or longer bunch trains
- Single bunch lengthening and instability in LER:
  - Impedance of the main beam pipe elements (resistive-wall, cavity, kickers and collimator) keeps reasonable bunch lengthening and high instability threshold
  - However, other elements may increase the bunch lengthening and decrease the instability level. To be evaluated

Synchrotron and Betatron Feedbacks

- R&D program has been carried out by using DAΦNE as test accelerator
- The last upgraded version of feedback for SuperB has been designed keeping in mind the following main points:
  - Maintain the legacy from the previous PEP-II/DAΦNE digital systems by upgrading all the hardware & software parts to the current commercially available solutions
  - Use the same digital system for betatron and synchrotron feedback to have an easier management and same operator interface
  - Implement at least 12-bit analog to digital conversion to minimize quantization noise in the correction signals and have an adequate dynamic range in the digital signal processing (previous feedback versions were working at 8 bits)
  - Cancellation or reduction of beam-beam enlargement effects due to the use of the feedback for a better compatibility with ultra-low emittance
  - Test on DAΦNE beams the new feedback systems with upgraded powerful diagnostics tools

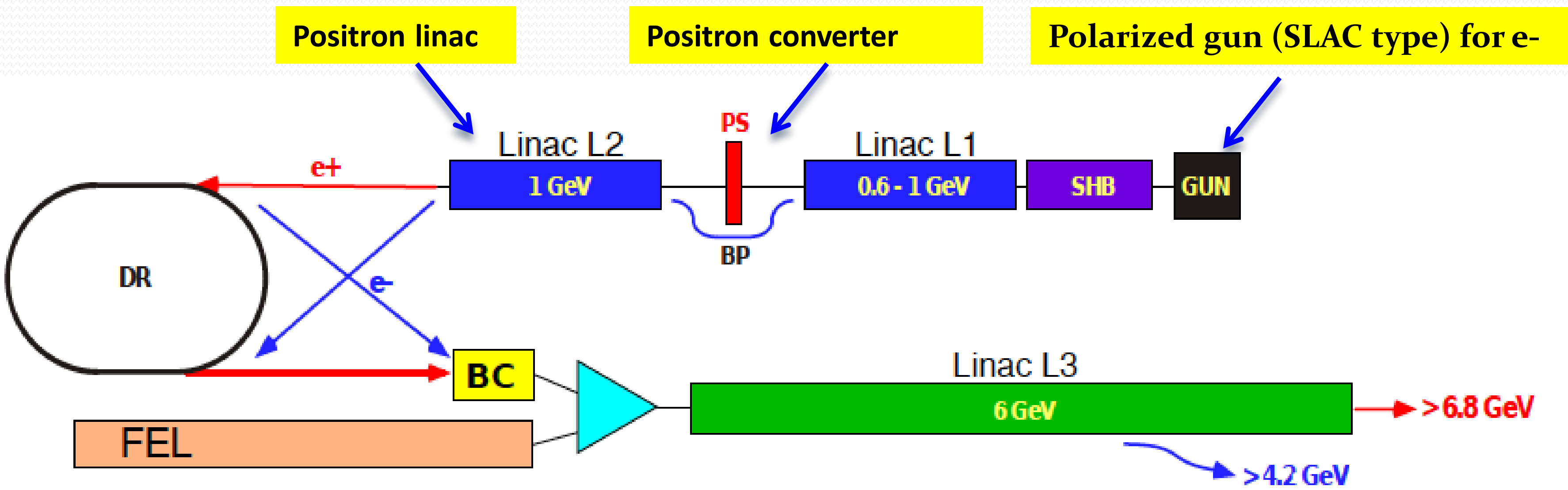


283 ms^{-1}, corresponding to a damping time of 3.5 μs [~10 revolution turns]



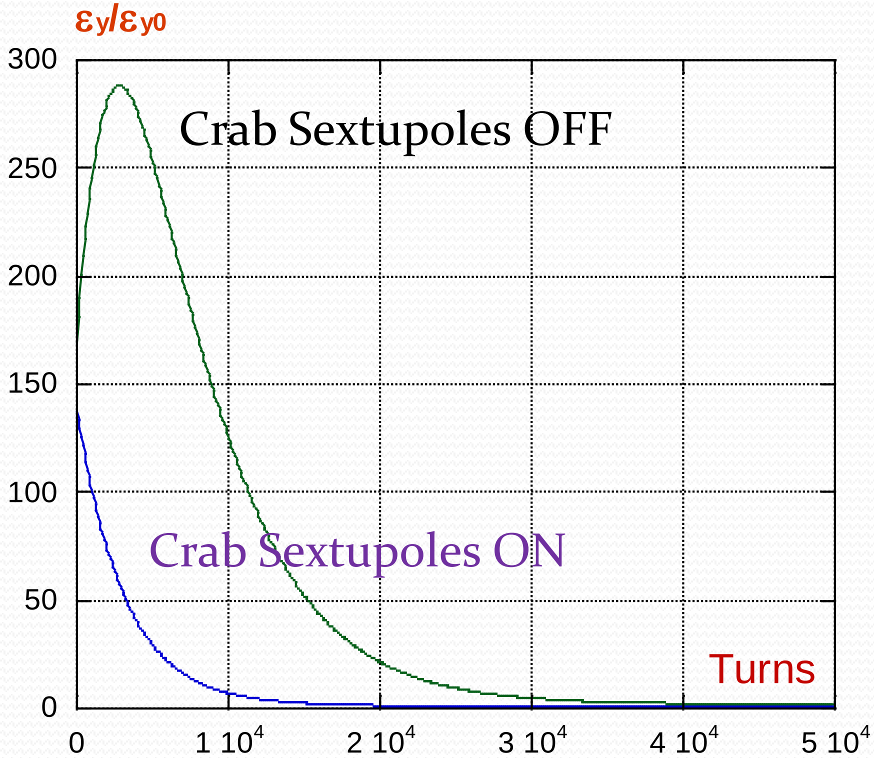
A. Drago

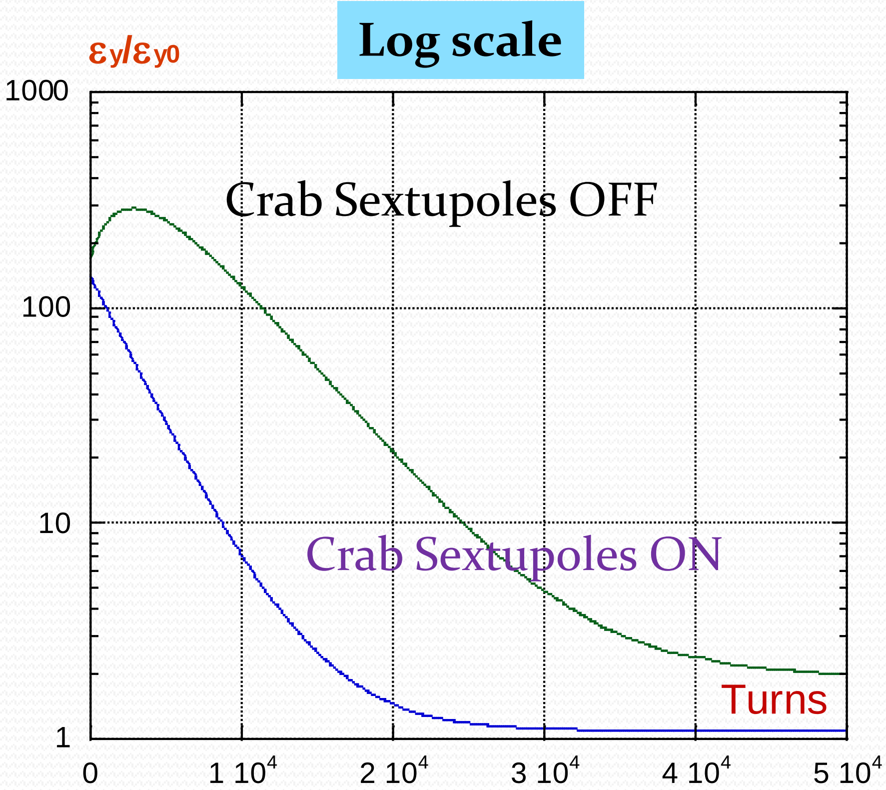
Injection system layout



- The injection complex consists of a polarized electron gun, a positron production system, electron and positron linac sections, a damping ring and the transfer lines connecting these systems to the collider main rings
- To keep the ultra high luminosity nearly constant, continuous injection in both rings, with high efficiency ~ 99%, is needed
- The charge required for injection into each ring is 300 pC/bunch in 5 bunches with a repetition cycle of 30 ms

Emittance evolution after injection, with and without crab sextupoles



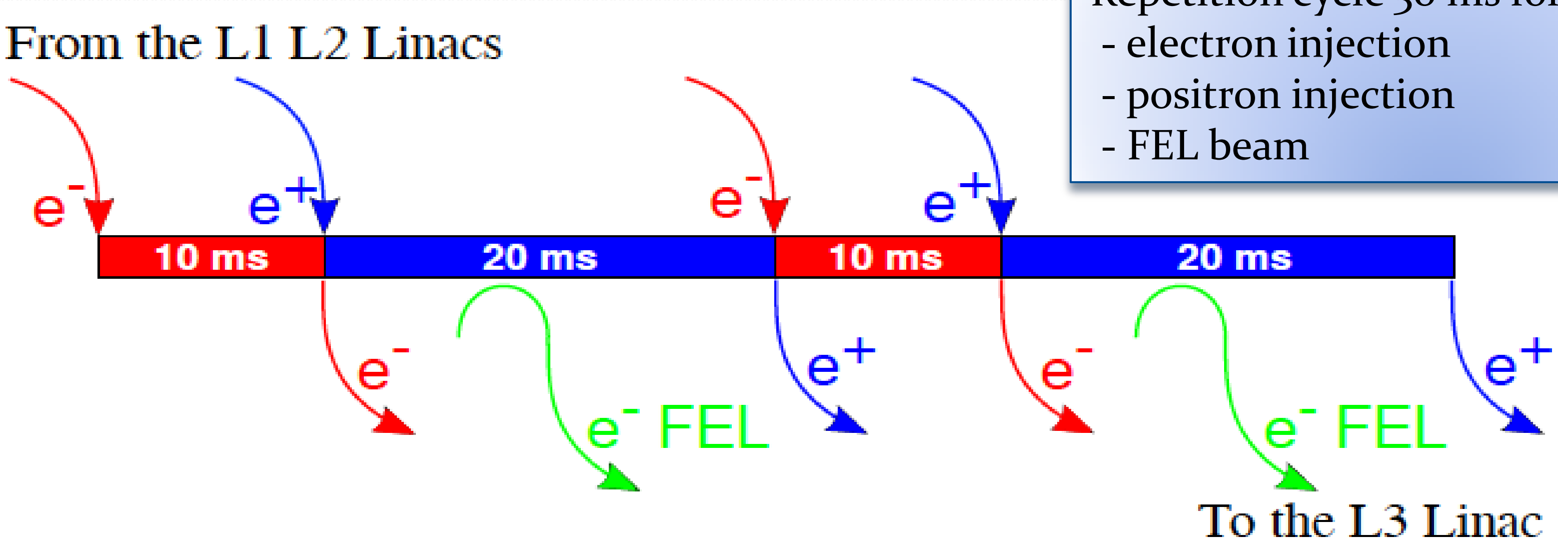


D.Shatilov

SASE X-FEL Integration

- The possibility to drive a SASE Hard-X FEL using the 6 GeV e^- linac has been recently considered
- Linac repetition frequency is 100 Hz →accelerate a pulse for the X-FEL during the store time of e+ in the DR, without affecting injection rate into MR →repetition cycle of 30 ms for each beam is possible: e+ injection, e- injection and a dedicated linac pulse for X-FEL

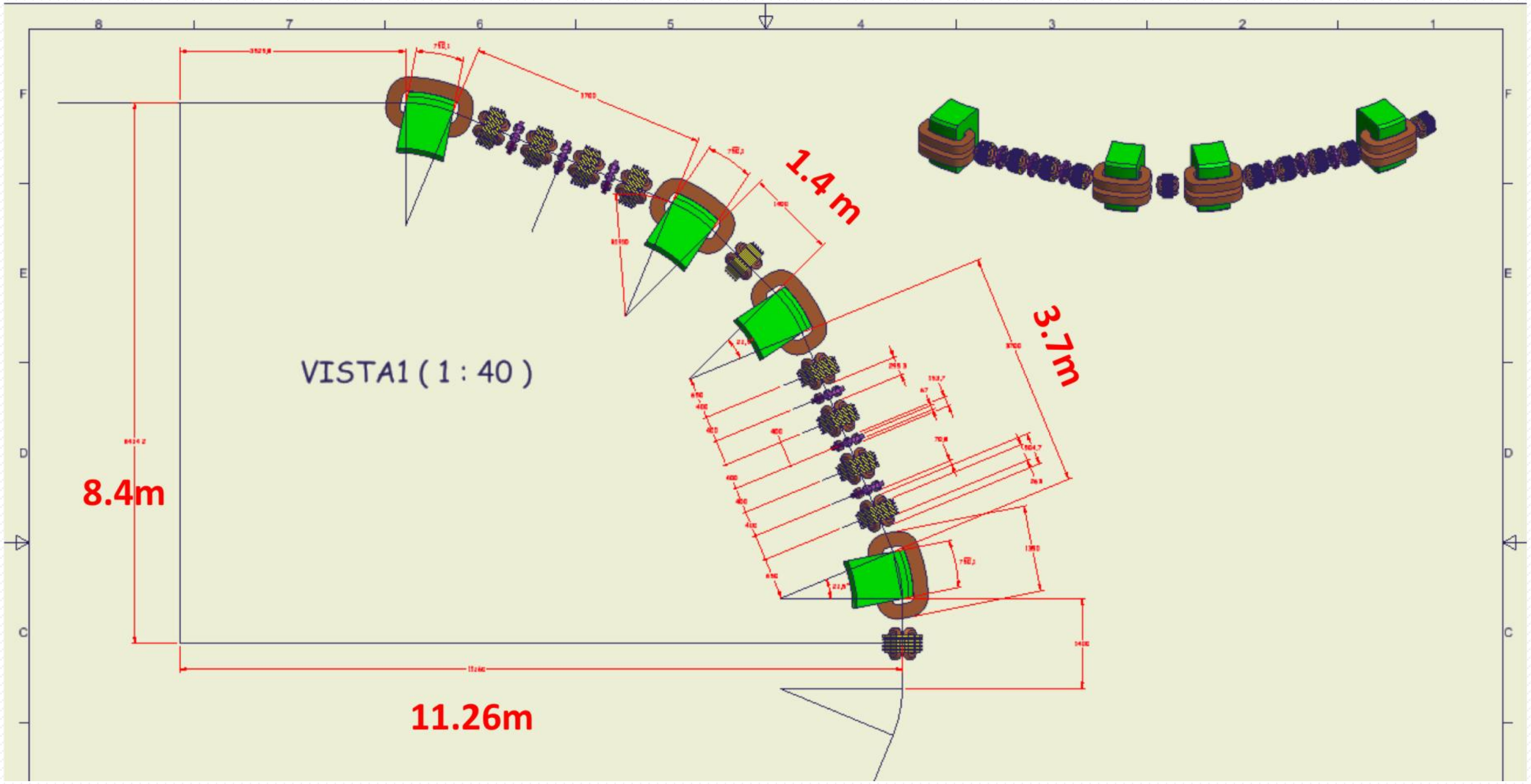
Repetition cycle 30 ms for each beam:
- electron injection
- positron injection
- FEL beam



Sources

- Electron Source:
  - e- produced using a polarized (Ga As) gun like the one used by the SLC collider at SLAC, where a polarization of 80% has been routinely achieved
  - A single e- bunch (or a short train of up to 5 bunches), with up to 10 nC charge is produced and goes through a subharmonic bunching system to reduce the bunch length from 1 ns FWHM down to 10 psec
  - e- are accelerated up to 1 GeV in linac L1 and injected into the Damping Ring
- Positron Source:
  - e+ are produced by electrons accelerated in linac L1, impinging on a positron converter target
  - Linac L2 is used to capture and accelerate e+ up to 1 GeV before DR injection
  - Studies on the e+ capture and acceleration system assure that the required positron yield is achieved with S-band linacs and a 1.5 GeV conversion efficiency
  - This solution has been preferred since it is well tested
  - An alternative solution, based on L-band capture and accelerating sections, has been studied and could be adopted later if it is proven that it can improve performances or reduce costs

Damping Ring Layout

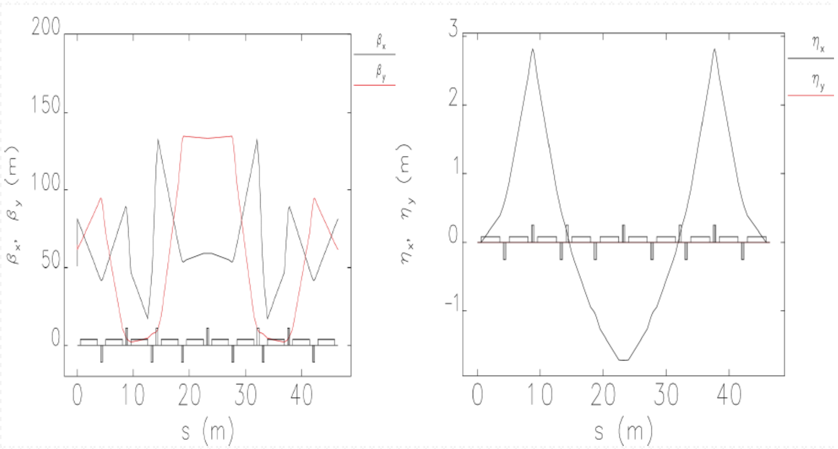


Drift spaces in the lattice have been modified to accommodate the real magnet dimensions as shown in the layout of one quarter of the ring

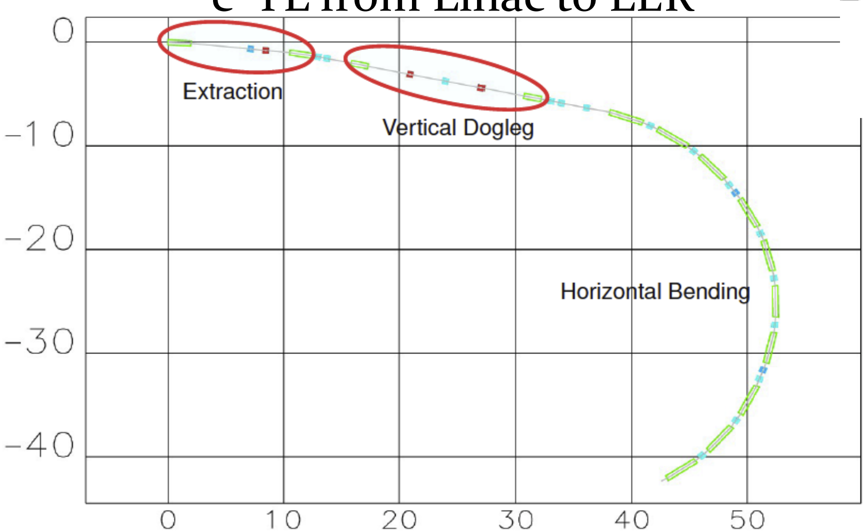
Linac

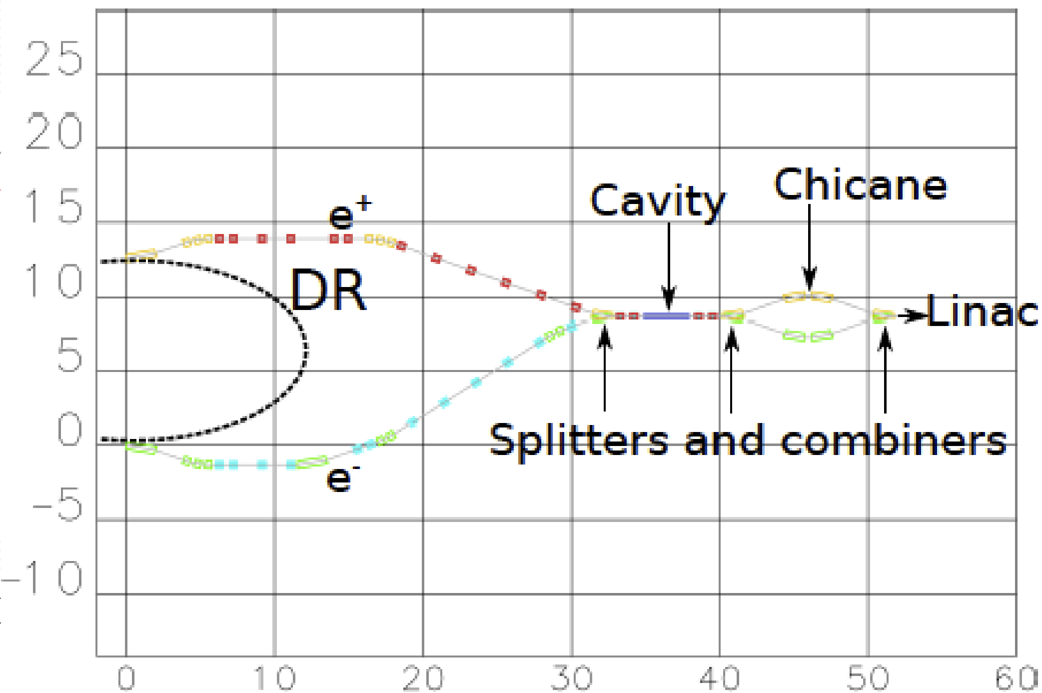
- In order to ease the design and the construction, the injector is based on the use of standard technology
- The S-band technology is available from several suppliers and is largely employed in many accelerator laboratories worldwide
- The 3 linac sections are based on S-band technology
- The accelerating structures are the 3 m., constant gradient, 2856 MHz units, known as SLAC-type sections
- They are equipped with SLED systems
- The linac sections are operated at 100 Hz repetition frequency and 23MV/m average gradient

Transfer lines to and from Linac



e^- TL from Linac to LER



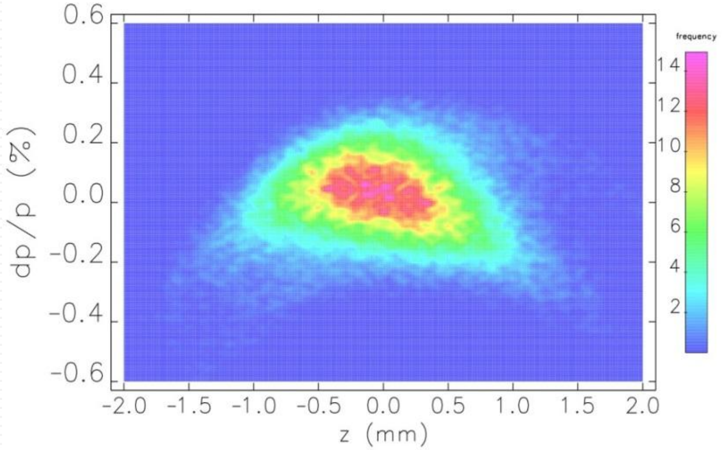


e^+ and e^- TLs from DR to Linac

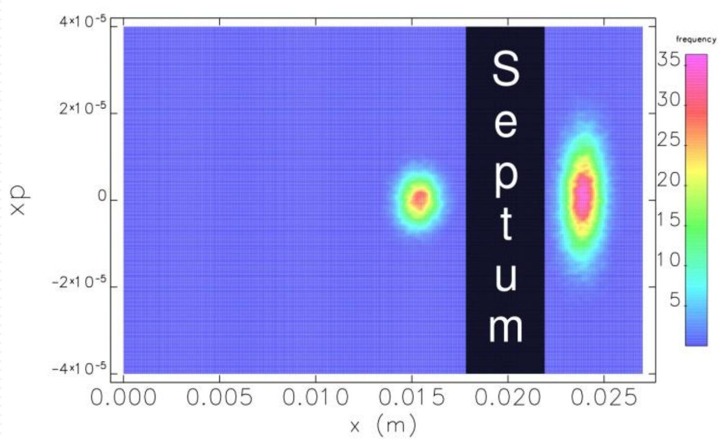
D. Pellegrini

Start to end simulation: DR to Main Ring

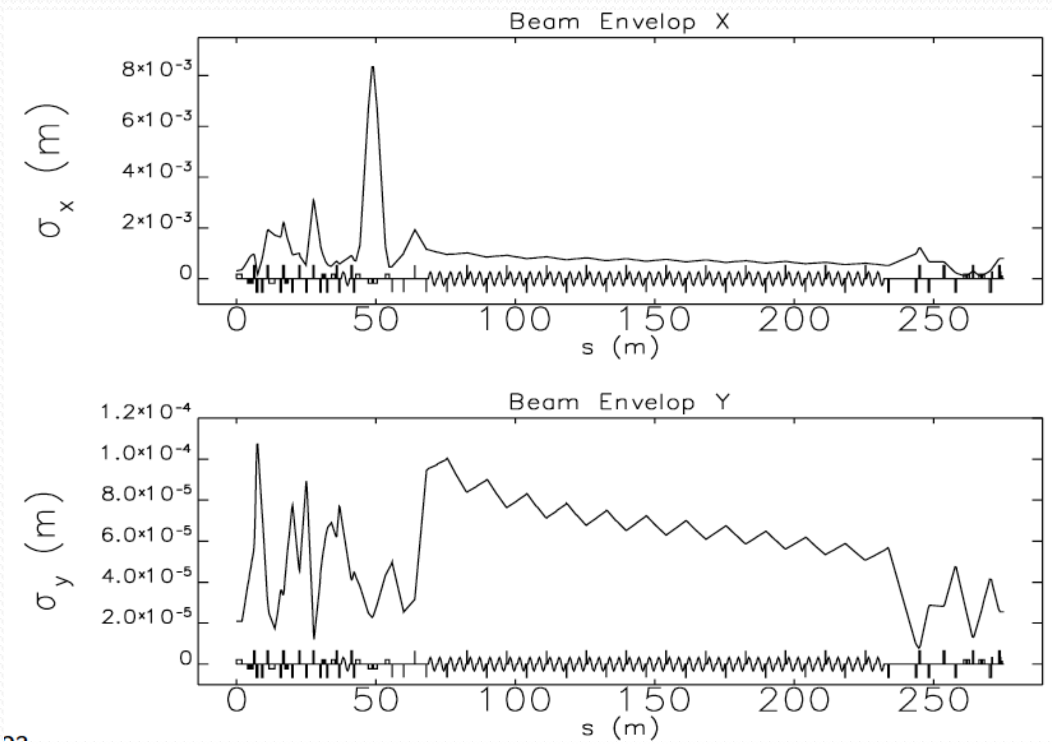
Long distribution after the linac - e⁻



x distribution at LER ring injection



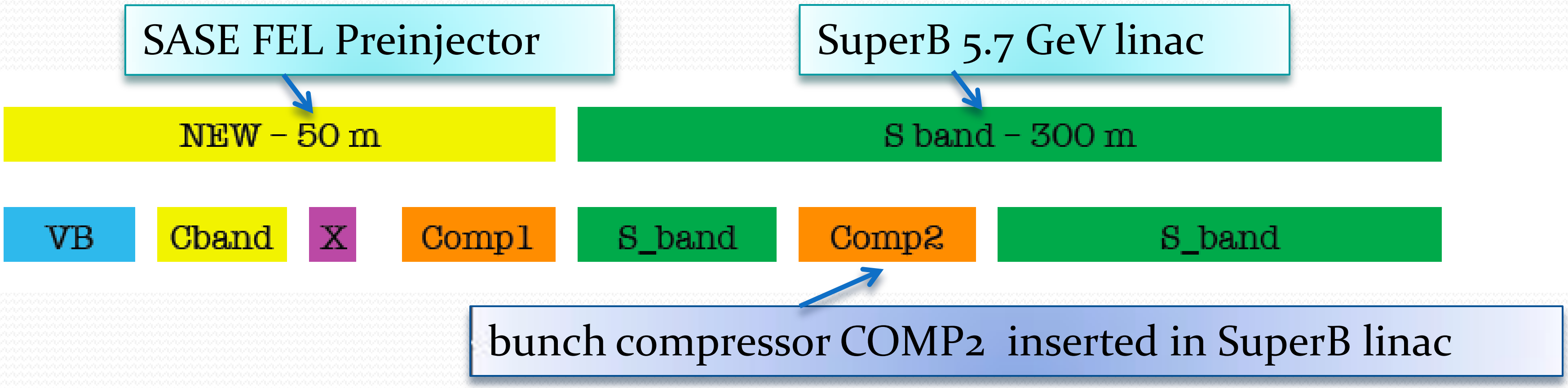
e⁻ beam envelope: from DR exit to LER ring injection cell



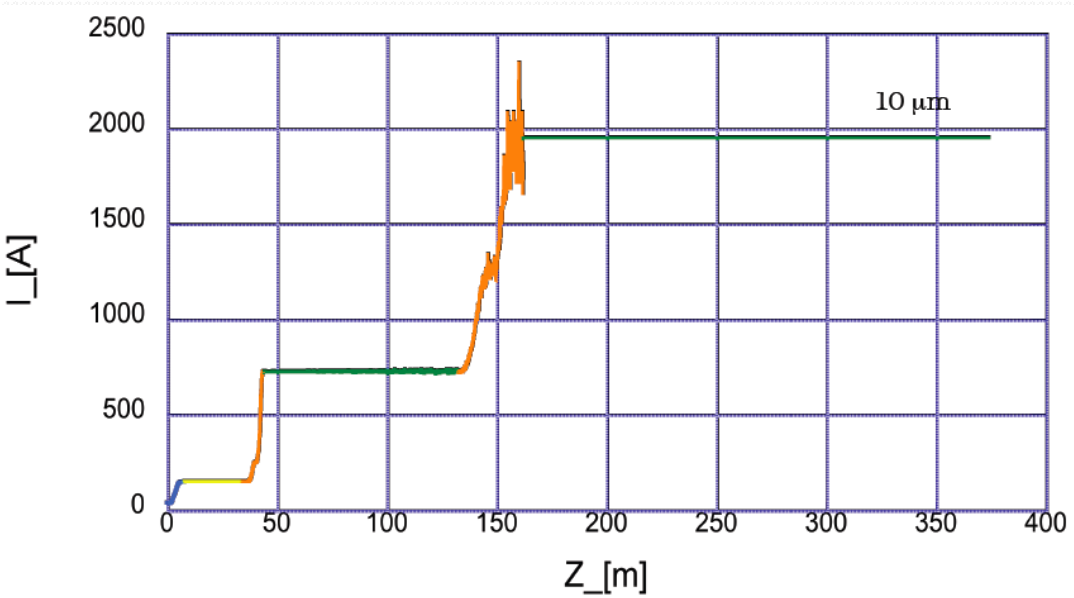
D. Pellegrini

SASE FEL option

M. Ferrario



Bunch peak current for the SASE FEL

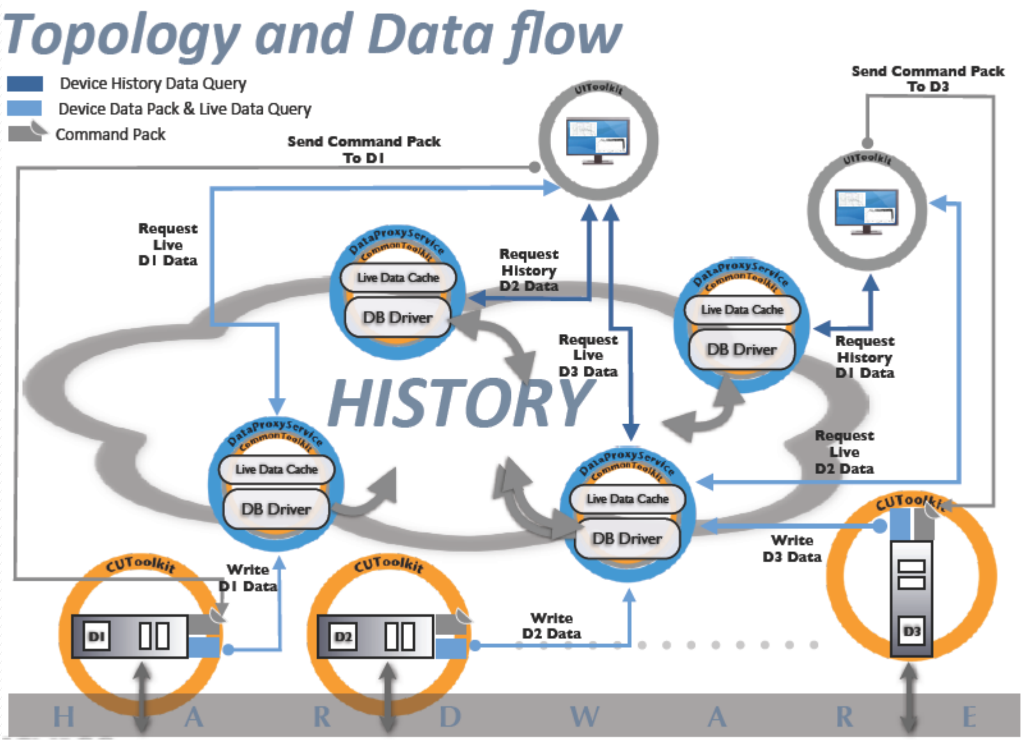


- A preliminary design study, based on FEL scaling laws supported by HOMDYN and GENESIS simulations, shows that a FEL source in the range of 1-3 Ang can be implemented still preserving the compatibility with the collider operation

G. Mazzitelli

R&D on Controls (!CHAOS)

- !CHAOS is developing a cloud of services dedicated to monitor and acquire, manage and store, present and elaborate the accelerator data as well as set values and execute commands



One of the main components of the recently developed framework is the historical engine, a cloud-like environment optimized for the **fast storage of large amount** of data produced by the control system's devices and services (I/O channels, alerts, commands, events, etc.), each with its own storage and aging rule.

!CHAOS is available in open source http://chaos.infn.it/

Conclusions

- SupeB Accelerator has reached a quasi-final design stage, layout is fixed and MR are ready to be engineered
  - work is needed on the optimization of non linearities in order to increase dynamic aperture and energy acceptance
- The main technical systems are being also finalised, but work is needed on
  - vacuum chamber design
  - impedance budget estimate
  - RF system (PEP-II RF will be used but needs some modifications and LLRF system has to be designed)
- The Cabibbo Laboratory has started hiring some personnel to be focused on the technical topics