Status of the SuperB Factory Collider

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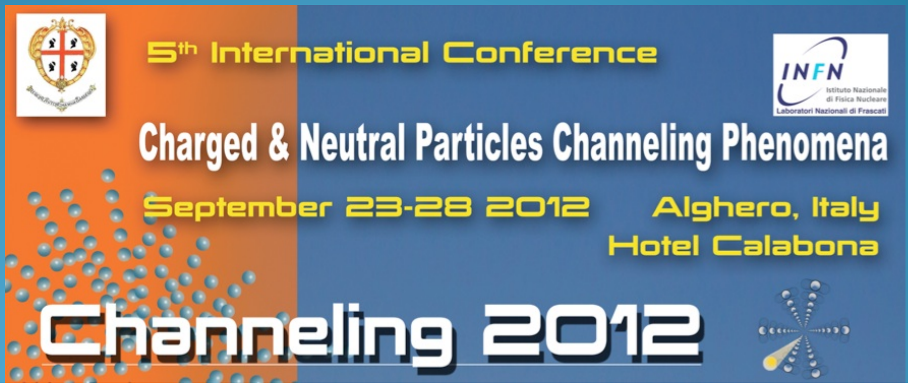
on behalf of SuperB Team
CH2012, Alghero, 23 September 2012



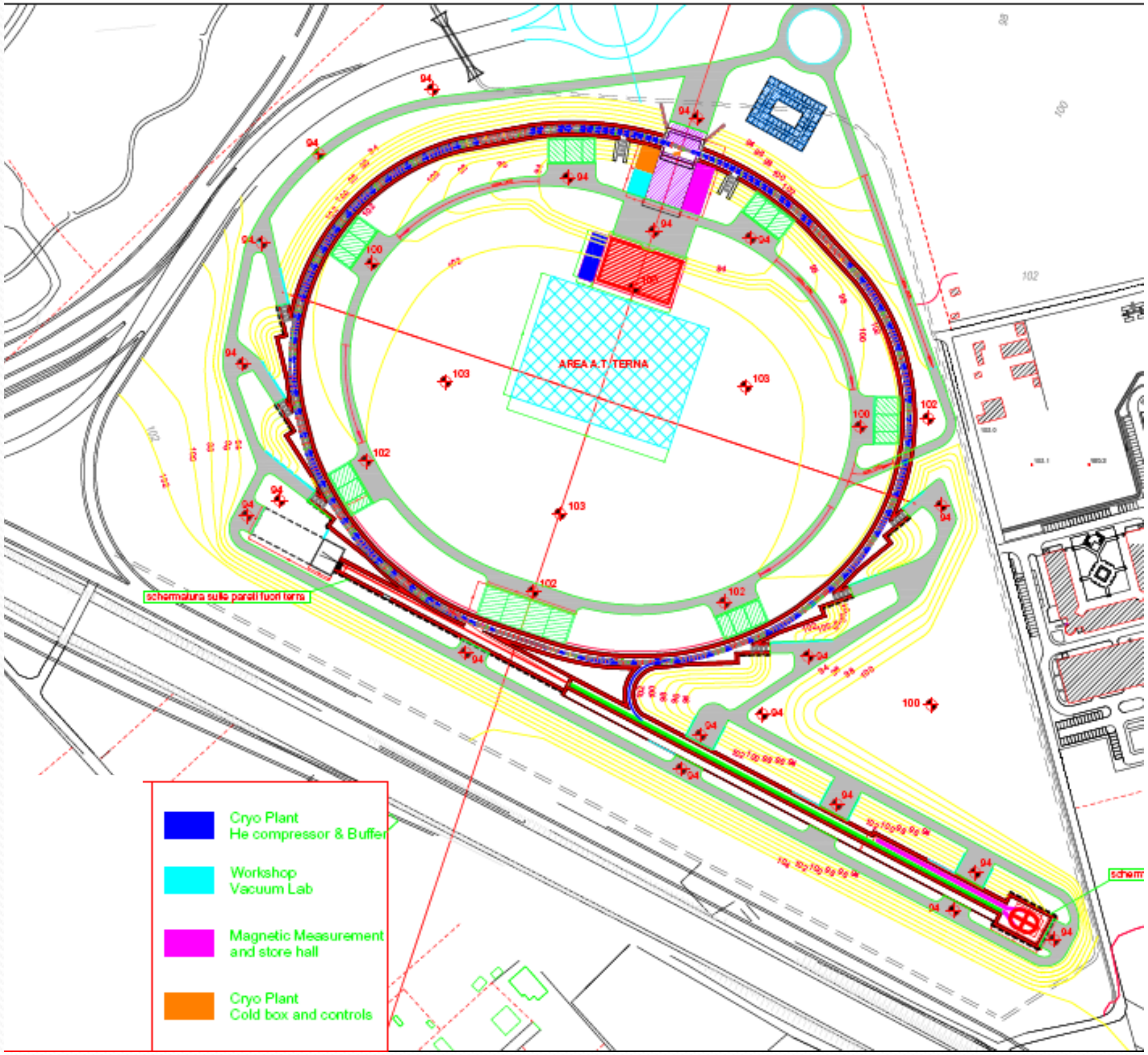
SuperB Collider

- SuperB is an asymmetric lepton collider aiming at a luminosity of 10^{36} cm^{-2} s^{-1} at the Y(4S) center of mass energy 10.6 GeV
- The target luminosity is ~ two orders of magnitude larger than that achieved by PEP-II (SLAC, USA) and KEKB (KEK, Japan)
- The leptons are stored in two rings (e^+@6.7 GeV, e^-@4.2 GeV) intersecting with a crossing angle at the interaction point.

Layout @ Tor Vergata University campus

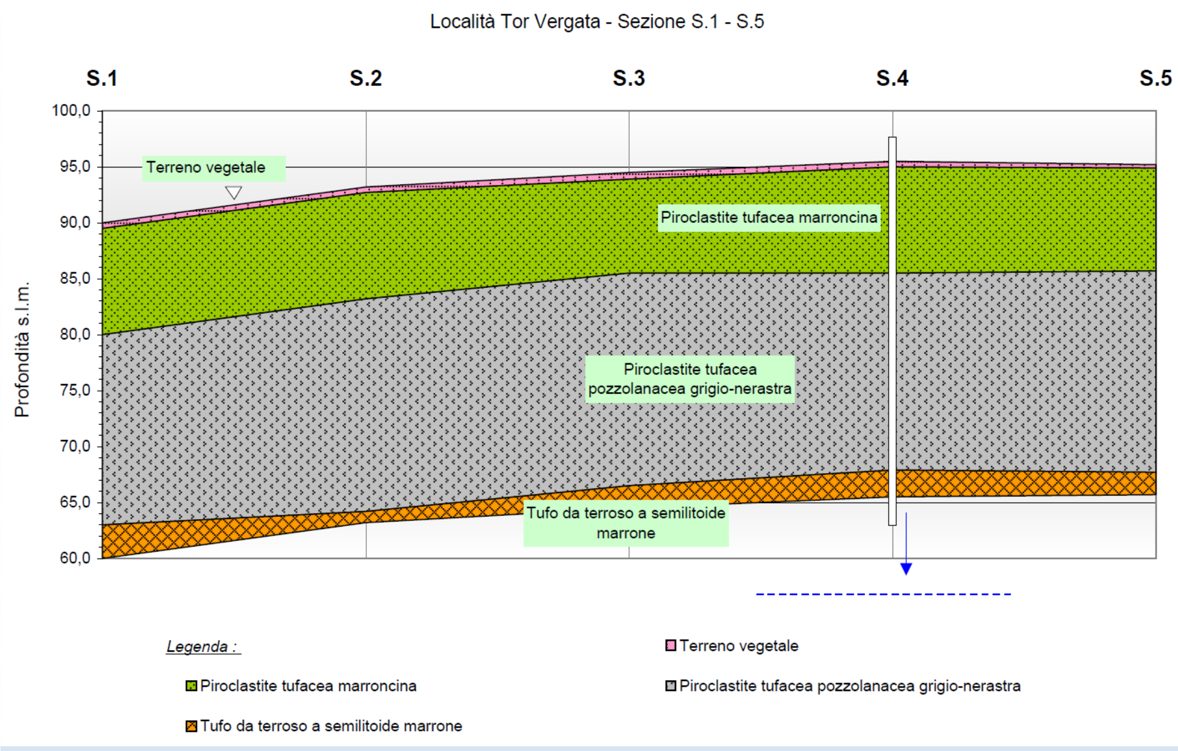
SuperB project has been approved by the Italian Government as part of the National Research Plan

Will be built by the Cabibbo Lab in the Tor Vergata University campus, just 5 Km away from the INFN Frascati National Laboratories.



Ground measurements

- Ground motion measurements performed on site show very «solid» grounds in spite of the vicinity of the highway, just 100 m away
- The highway is at higher level with respect to the site, and the traffic vibrations («cultural noise») are very well damped

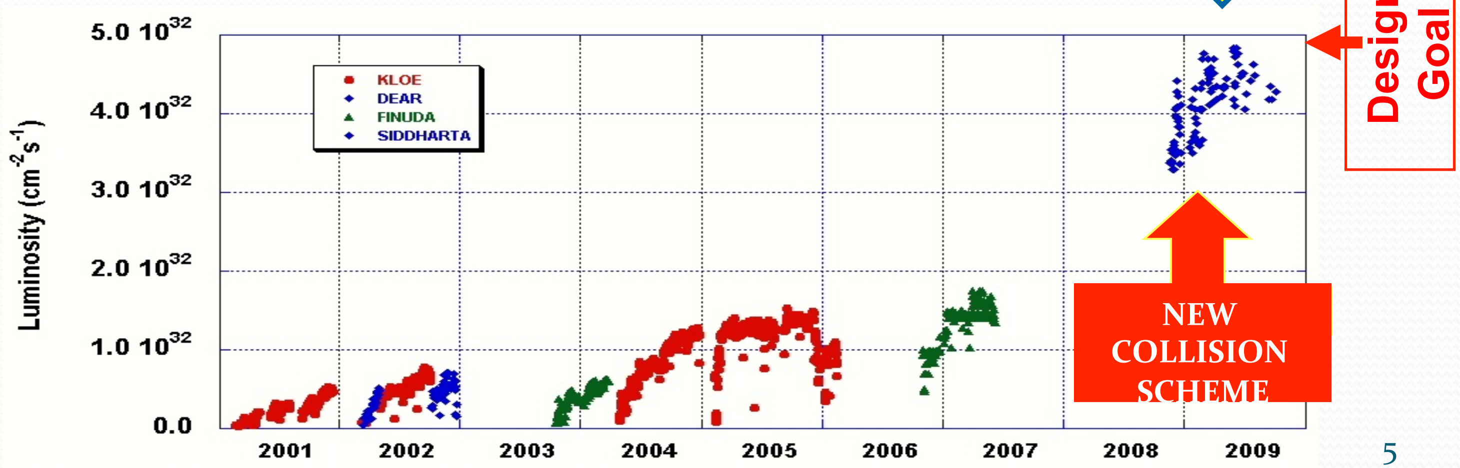


Ground x-section
Volcanic soil

SuperB-Factor design in a nutshell

- To break B-Factories record in peak luminosity a new collision scheme is needed
- The «Large Piwinski Angle» and «crab-waist sextupoles» option was first developed by P. Raimondi and tested at DAΦNE (LNF)
- Large crossing angle and very small beam sizes:
  - collision area is shorter
  - IP β functions can be smaller
  - less parasitic crossings

$$\Phi_{Piwinski} = tg(\theta)\sigma_z/\sigma_x$$



SuperB-Factory design in a nutshell

- Longitudinal overlap area now related to horizontal beam size not to bunch length, so it can be greatly reduced allowing a reduction of:
  - Vertical beta, beam size, hourglass and tune shift
  - Horizontal tune shift (1D beam-beam)
- «Crab-waist» sextupoles at a proper phase with respect to the IP:
  - suppress most of XY resonances
  - tunes area for operation is larger
- Same Luminosity with lower currents:
  - lower HOM heating
  - less power consumption

Design requirements & challenges (some!)

- Extremely small emittances, both H and V, comparable to those achieved in the last generation SR sources or planned for linear colliders Damping Rings
- Strong IP doublets:
  - SC quads in a restricted space
  - separated beams
  - control of background rates
  - physical aperture
- Coupling & chromaticity correction in the IR
- Dynamic aperture with crab sextupoles
- Control of vibrations at IP
- Sensitivity to magnets alignment errors → Low Emittance Tuning
- Touschek lifetime and IBS emittance growth

Super B main parameters

Parameter	SuperB	
	HER (e^+)	LER (e^-)
Luminosity ($cm^{-2}s^{-1}$)	10^{36}	
C (m)	1200	
E (GeV)	6.7	4.18
Crossing angle (mrad)	60	
Piwinski angle	20.8	16.9
I (mA)	1900	2440
$\varepsilon_{x/y}$ (nm/pm) (with IBS)	2/5	2.5/6.2
IP $\sigma_{x/y}$ (mm/nm)	7.2/36	8.9/36
σ_l (mm)	5	5
N. bunches	978	
Part/bunch ($x10^{10}$)	5.1	6.6
σ_E/E ($x10^{-4}$)	6.4	7.3
bb tune shift (x/y)	0.0026/0.107	0.004/0.107
Energy loss/turn (MeV)	2.1	0.86
Total beam lifetime (s)	254	269
Polarization (%)	0	80
RF (MHz)	476	

SuperB design & progresses

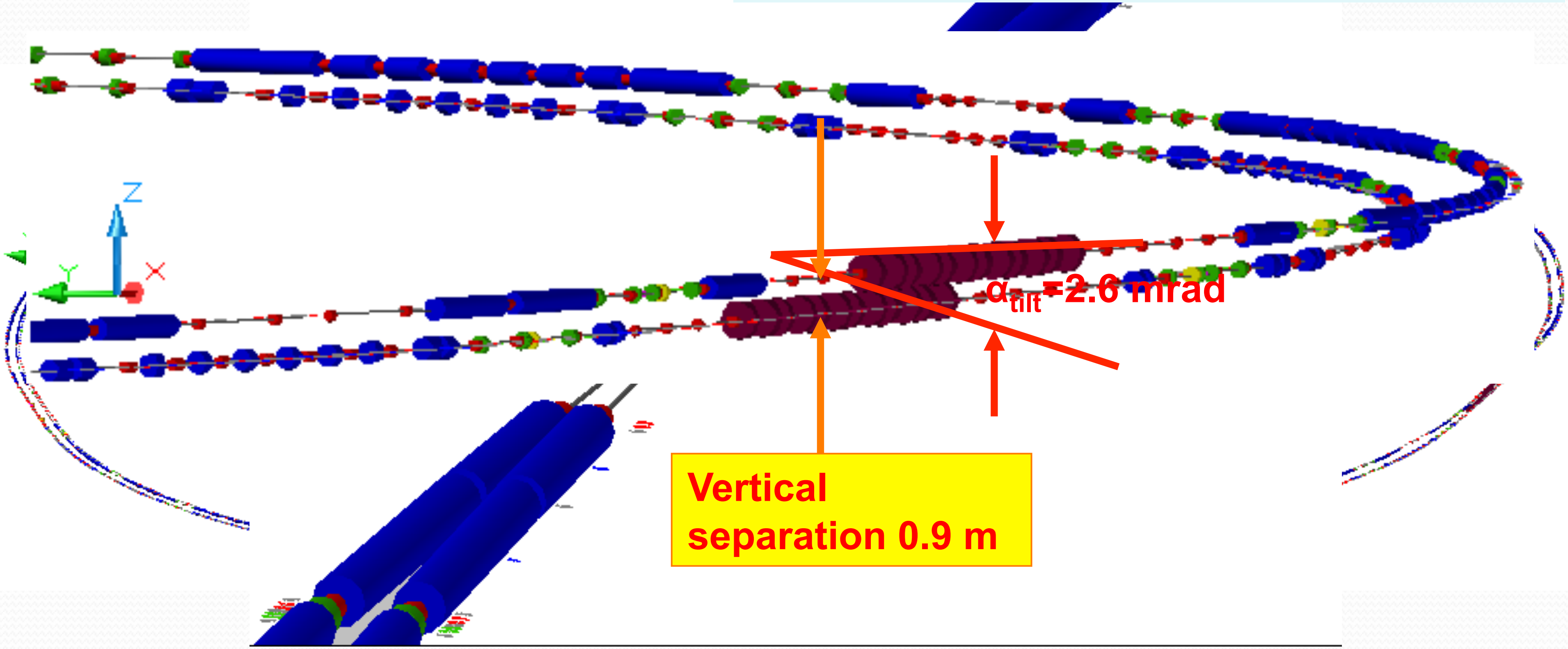
- Large Piwinski angle and crab-waist sextupoles
- Relatively low currents → lower power consumption
- Re-use of some PEP-II components
- Longitudinal polarization of e^- beam (70-80% @ 4.18 GeV)
- Possibility to run at lower energy (τ/charm threshold)
- Twin SC IP doublets of «new» design
- «Green field» accelerator, 5 Km to Frascati Labs
- «Nicola Cabibbo Laboratory» newly constituted will be in charge of construction and operation
- Accelerator management has been appointed and recruitment of the first personnel is in progress
- Design of principal systems is close to be frozen
- A review of the cost estimate has been done based on the present baseline lattice

Main Rings

- The two rings have similar geometry and layout, except for the length of dipoles
- The arcs cells have a design similar to that of Synchrotron Light Sources and Damping Rings in order to achieve the very low emittances needed
- Rings are hosted in the same tunnel, separated about 2 m in horizontal and 1 m in vertical (opposite to IP)
- In the latest version of the lattice some cells suitable for SR Insertion Devices have been inserted. This is an open option to be exploited probably after the collider lifetime (tunnel will have possibility to extend SR beamlines from both rings)

Rings layout

- Circumference 1200 m
- Horizontal separation of arc ~2 m
- Vertical separation of RF section 0.9 m



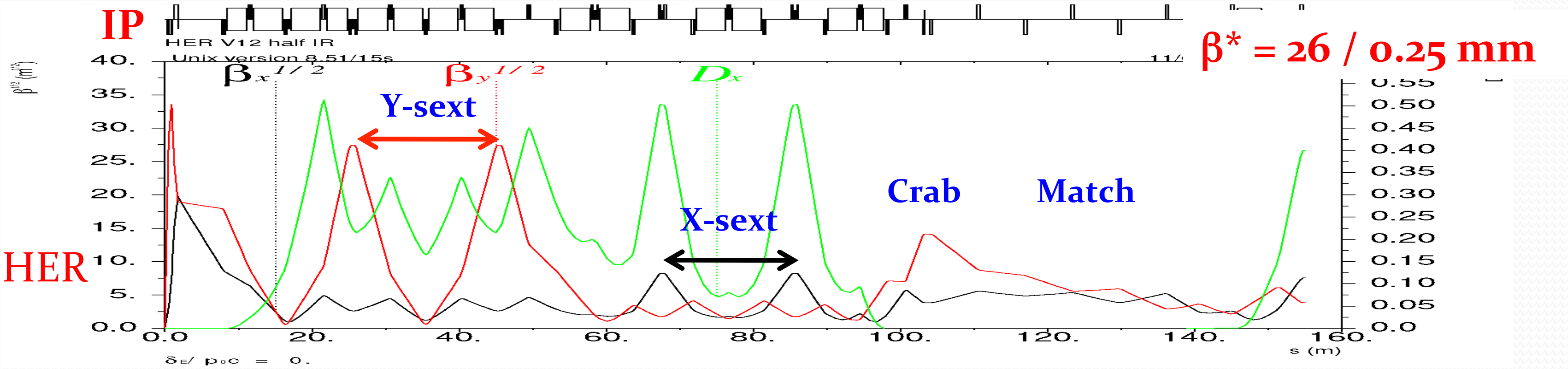
Small tilt at IP (by small solenoids not vertical bends) provides ~1 m vertical separation at the opposite point: (a) e+e- rings separation, (b) better equipment adjustment, (c) SR beamlines from both rings is possible

Lattice – Non linear effects

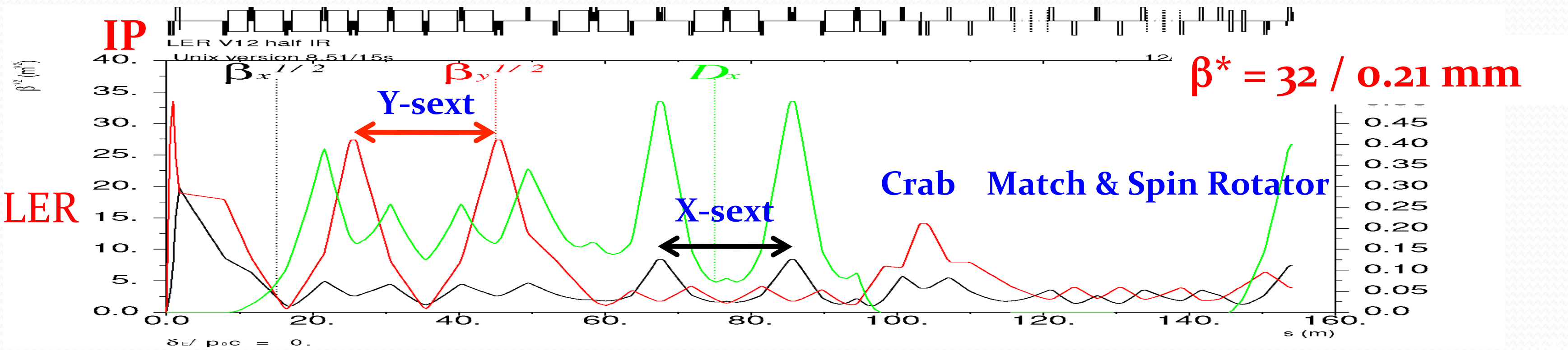
- Dynamic aperture is very sensitive to nonlinear magnetic fields of FF → precise modeling of IR beam optics is indispensable
- Normal and skew higher multipoles are included in the lattice model
- Nonlinear fields associated with the final quadrupoles and skew multipole fields along the beam line in the non-uniform solenoid fields are also taken into account
- Optimization of higher multipoles and compensation solenoid fields are in progress by checking their impact on the dynamic aperture

Final Focus sections

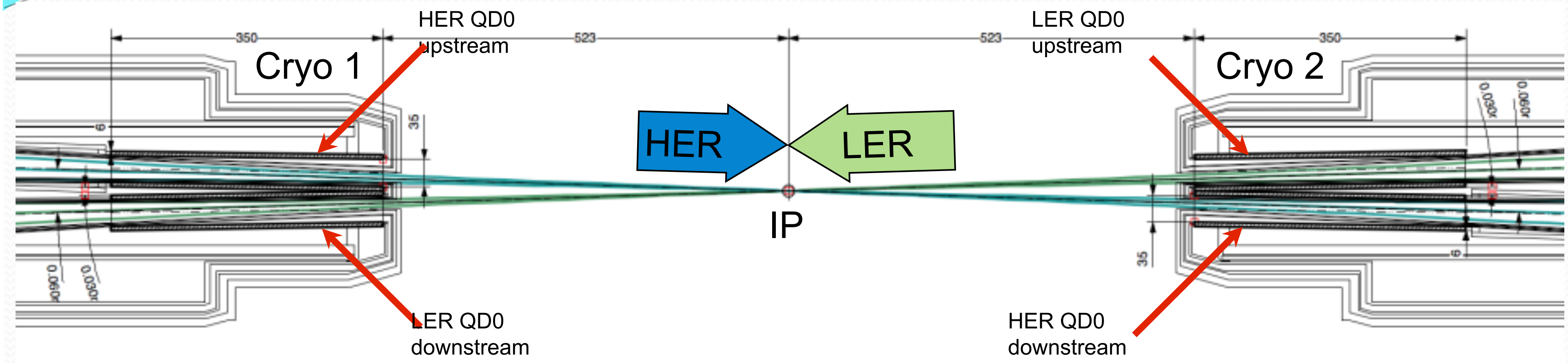
"Spin rotator" optics is replaced with a simpler matching section



Matching section is shorter than HER to provide space for spin rotator optics.
±30 mrad bending asymmetry with respect to IP causes a slight spin mismatch between SR and IP resulting in ~5% polarization reduction.



IR design

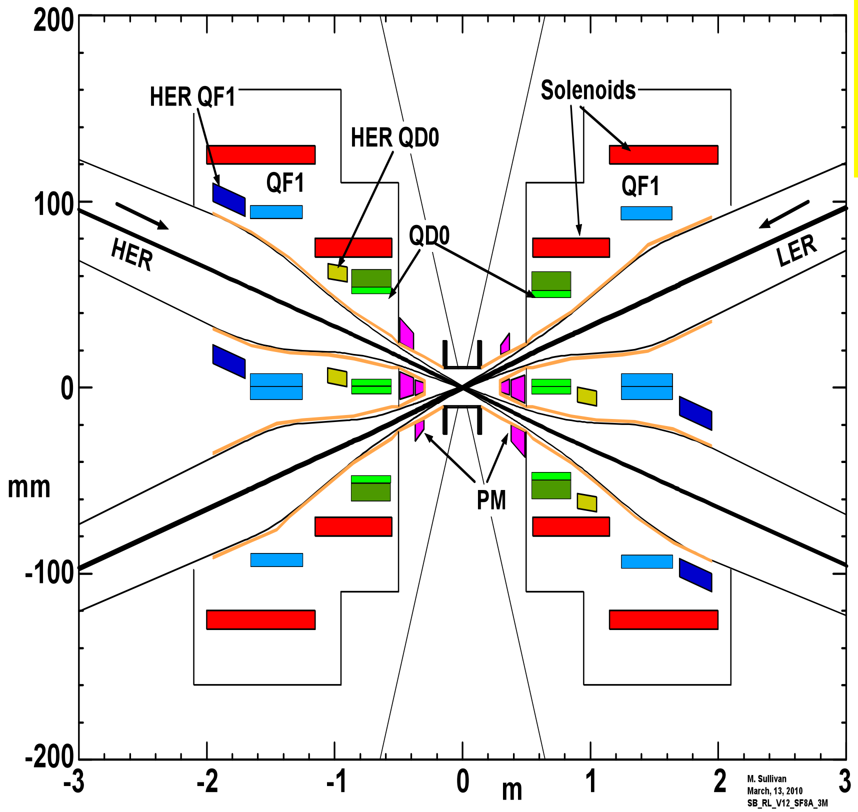


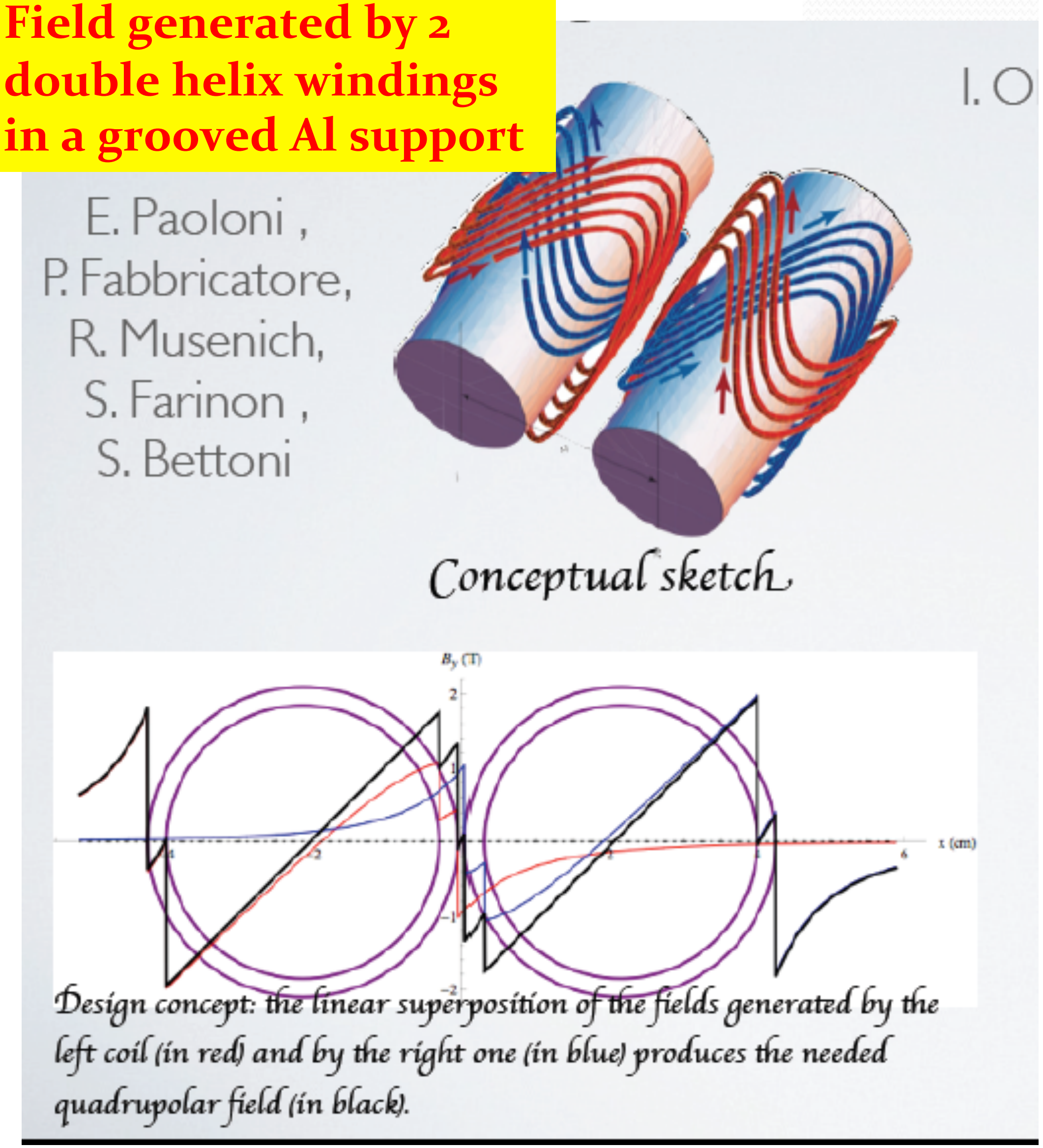
- With the large crossing angle a shared quadrupole layout is not viable, since the displacement of the magnetic axis with respect to the nominal trajectories will generate unmanageable backgrounds by steering off energy particle in the detector
- A new design of the first doublet with «twin» quadrupoles was then developed
- They must generate a large field gradient (100 T/m) to obtain β_y~0.2 mm at IP
- The thermal load on the QD0 beam pipe section must be evacuated at room temperature hence a cold pipe design is not feasible

IR Design

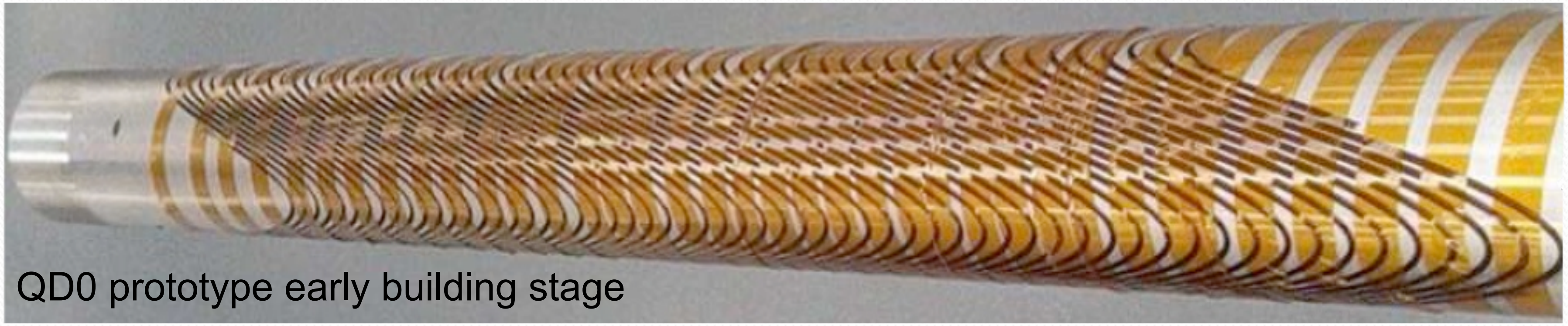
QDo, Design

Field generated by 2 double helix windings in a grooved Al support





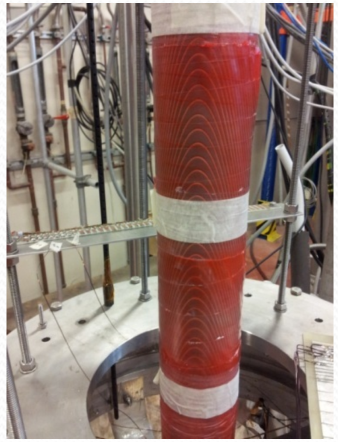
QD0 prototype

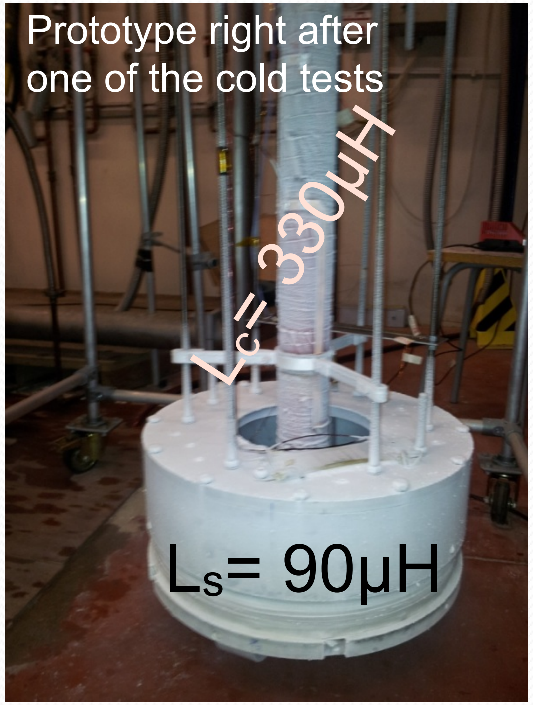

QD0 prototype early building stage

- Main goal of the prototype is to study its behavior during a quench
- Magnetic design is based on the double helical concept
  - Excellent field quality on almost the whole mechanical aperture
  - Possibility to produce arbitrary combinations of multipolar fields by a clever design of the winding shape
- NbTi SC wire for a nominal current of 2650 A
- Inner bore diameter is 50 mm to accommodate for a rotating coil device to measure the generated field quality

Cold test of the QD0 prototype

- An SC current transformer was built to feed the prototype
  - The total energy to be dissipated during quench is the one stored in the small secondary + the quadrupole ~ 1.4 kJ
  - A conventional power supply + quench detecting system and quench heathers will hardly (if ever) protect the magnet from disastrous thermal shocks
- The model was successfully tested. IT WORKS!
- Training process started at ~ 2300 A with the first quench. The magnet quickly improved its maximum current handling capability operating in steady state at its design current
- The subsequent quenches occurred at current exceeding 2750 A. The limitation seemed to be of mechanical nature. Further test are under way for better investigate this aspect





Prototype right after one of the cold tests

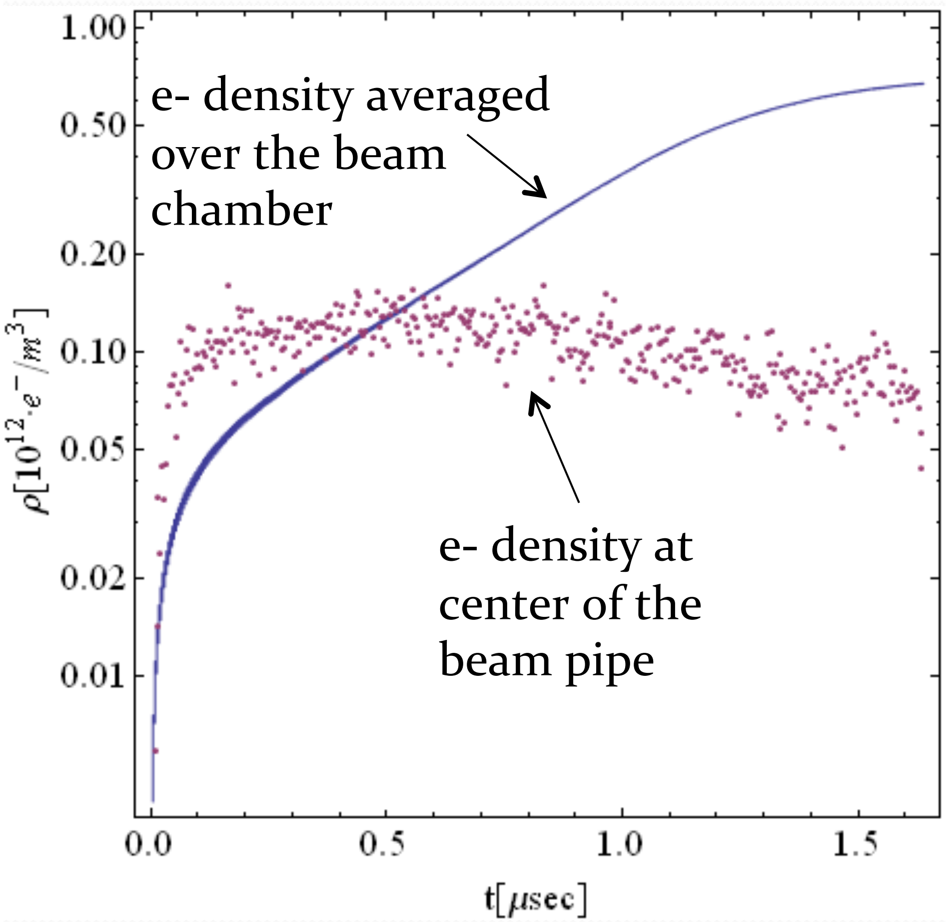
Collettive effects

- Stored beams are subject to effects that can produce instabilities or degrade the beam quality, such as:
  - Intra-Beam-Scattering (IBS) inside the bunch produces emittance and energy spread growth
  - Electron-cloud instability limits the current threshold of the positron beam → needs mitigation methods (ex. solenoids, beam pipe coating, clearing electrodes…)
  - Fast Ions Instability is critical for the electron beam
- Most of these effects have been studied and remediation techniques chosen

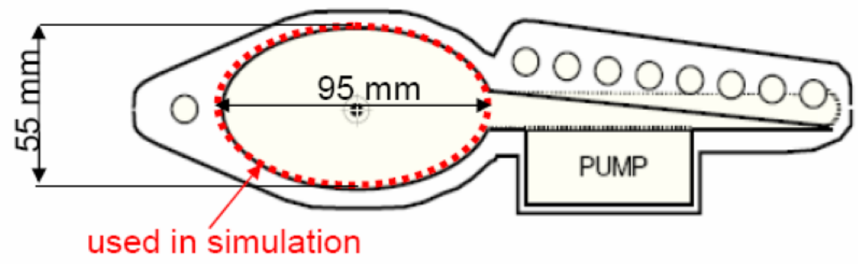
e-cloud buildup in HER Dipoles

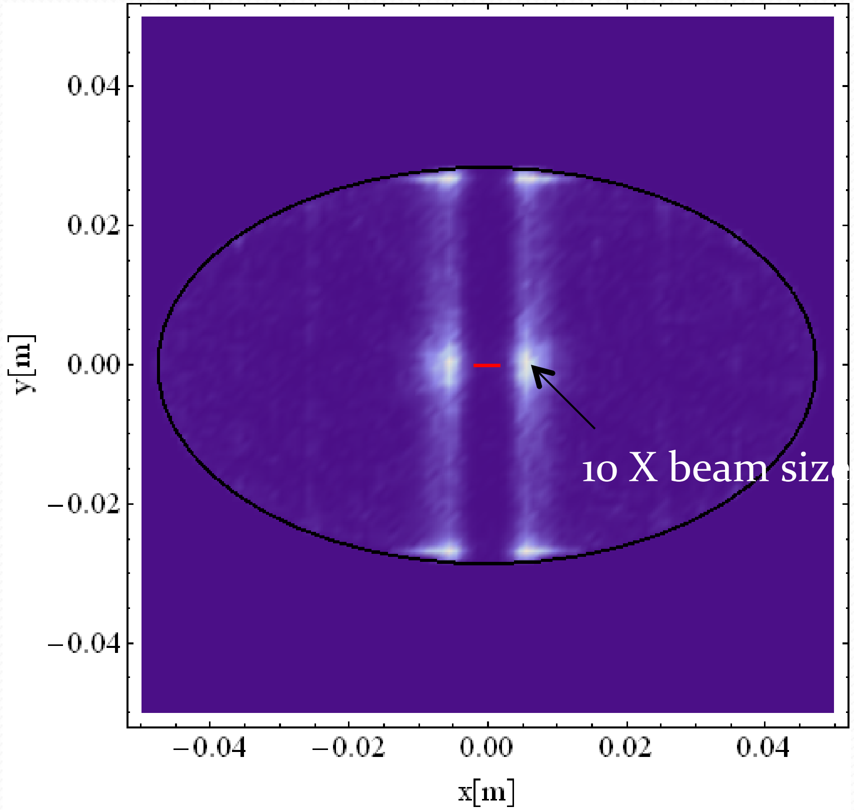
Demma

By=0.3 T; η=95% SEY=1.1



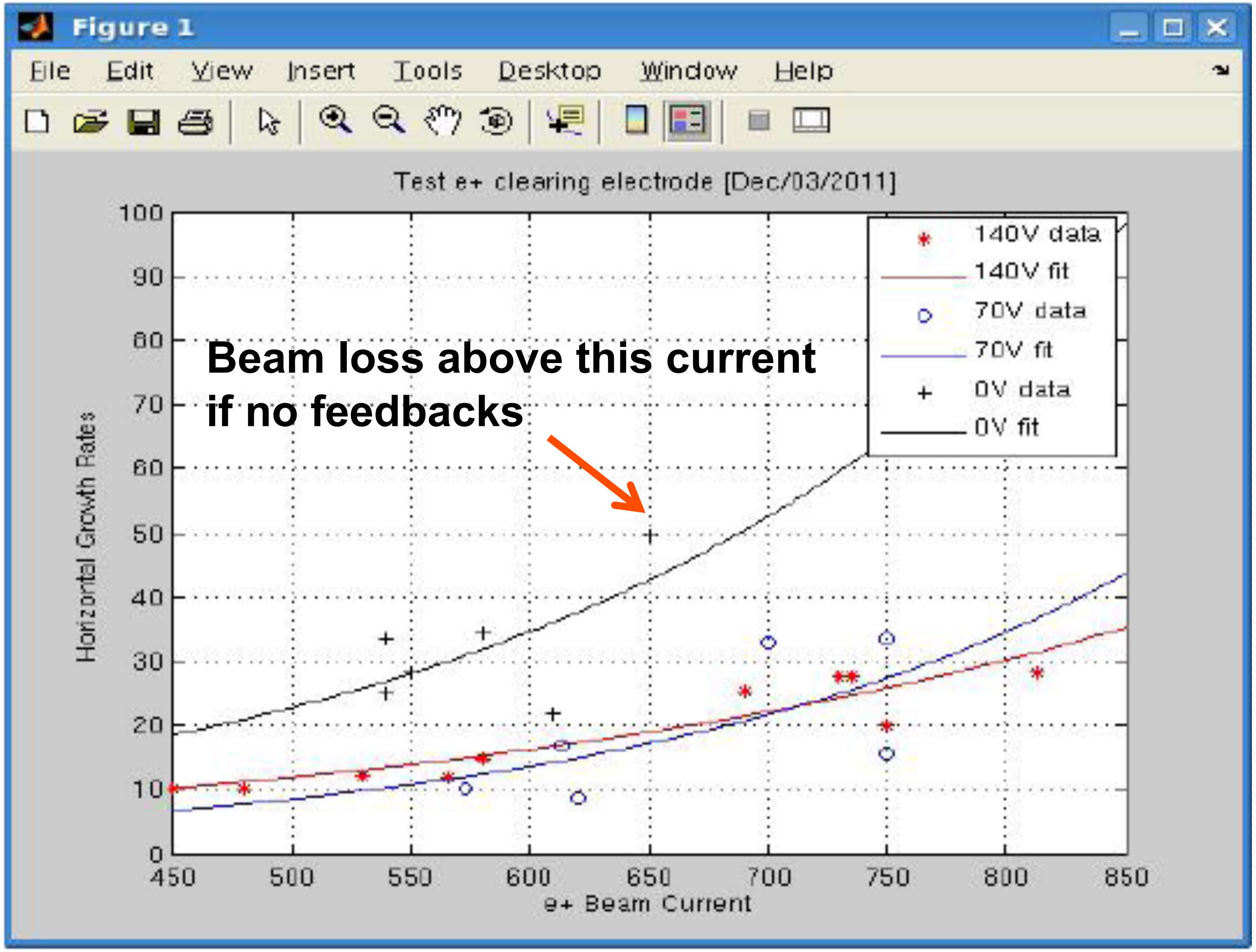
LER dipole vacuum chamber (CDR)





Test of e-cloud clearing electrodes at DAΦNE

Horizontal growth rate measurements



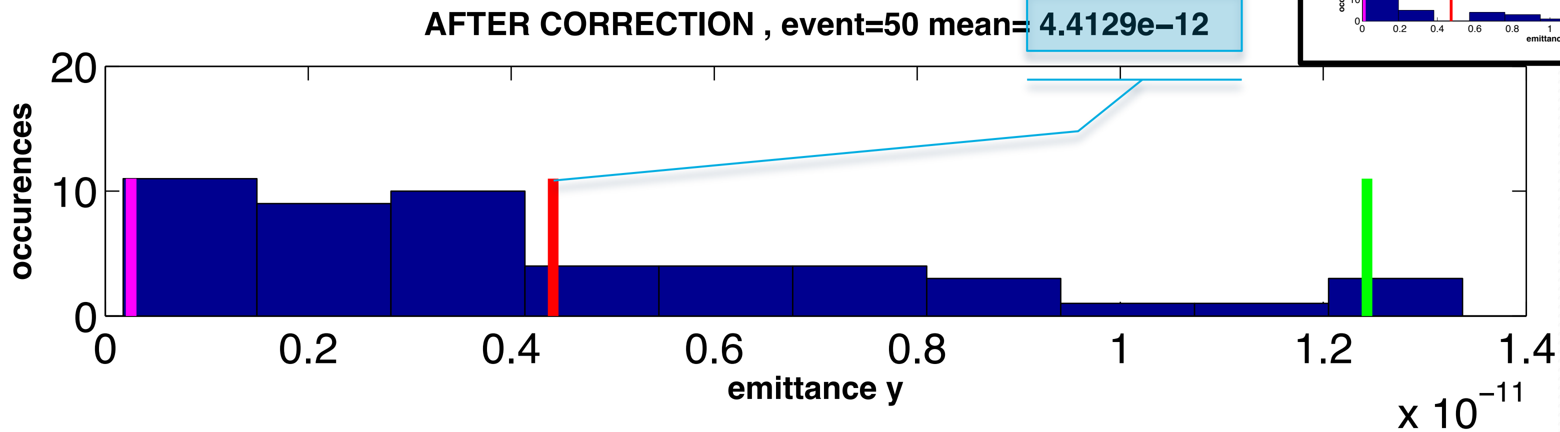
Very positive results: vertical beam dimension, tune shift and growth rates clearly indicate the good behaviour of these devices, which are complementary to solenoidal windings in field free regions

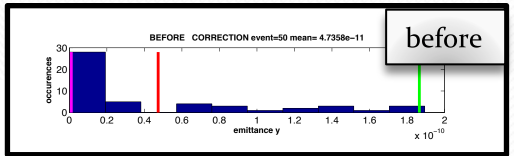
D. Alesini, IPAC12

Low Emittance Tuning

- Extremely low beam emittances → careful correction of all magnets and BPM alignment and field errors
- An efficient and fast tool has been implemented and tested at DIAMOND and SLS, to correct orbit-dispersion-coupling and to detect the source of magnet and BPM errors
- Tables of error tolerances are being produced for SuperB

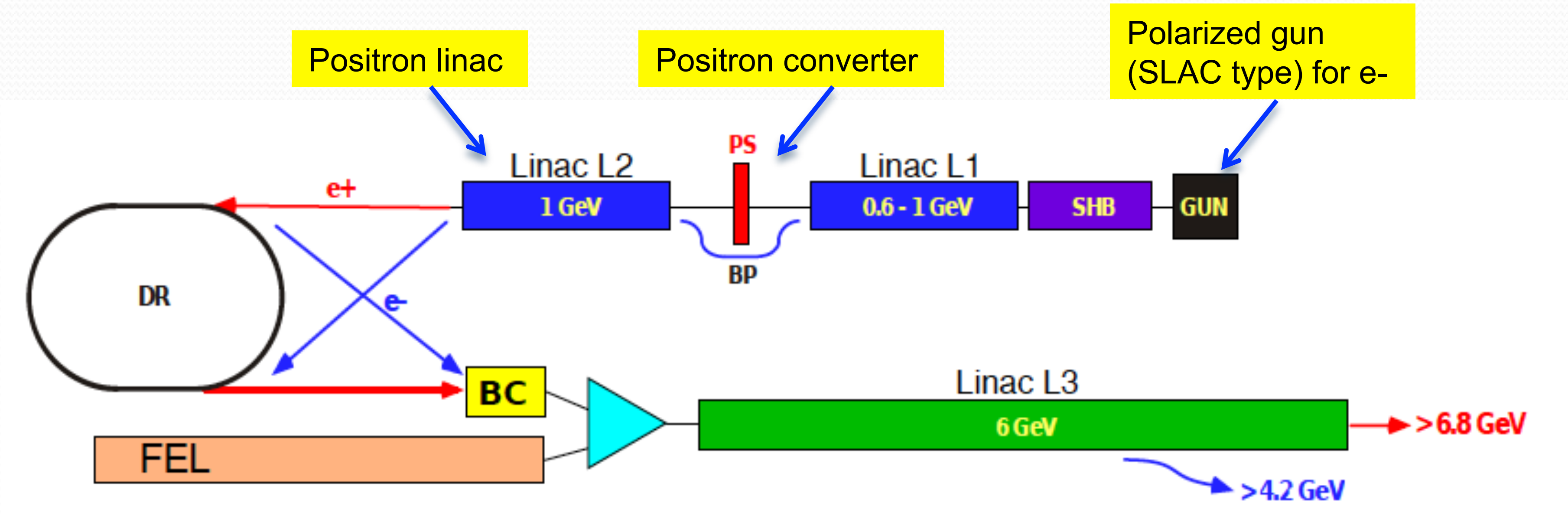
50 random sets, correcting with LET for 2 iterations after 3 orbit pre-correction iterations





S. Liuzzo, IPAC12

Injection system layout

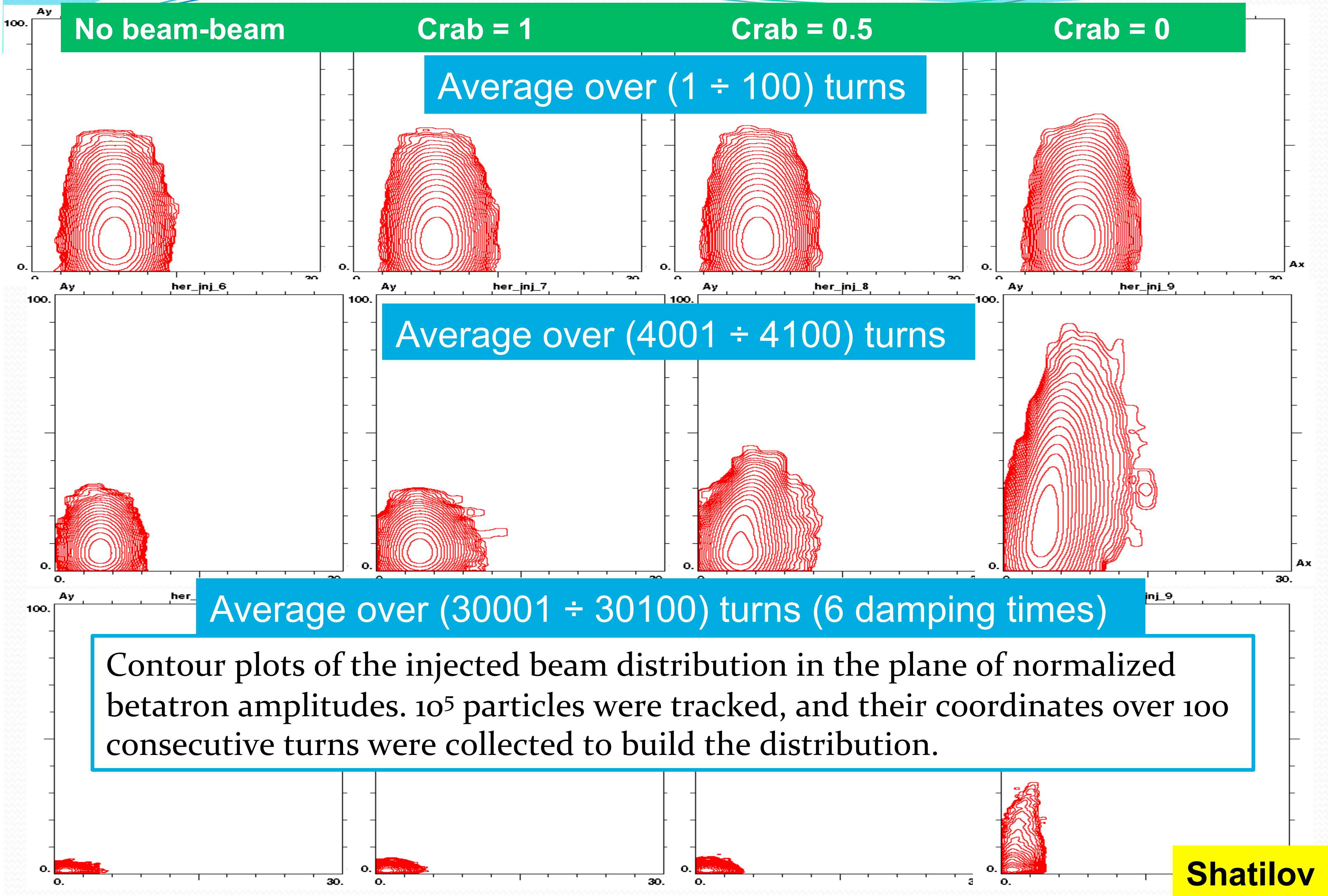


At a luminosity of 10^{36} $cm^{-2}s^{-1}$ beam lifetime is limited by Bhabha scattering at IP to ~ 5 min

To keep nearly constant such a high luminosity continuous injection in the two rings of the collider, with high efficiency ~ 99%, is needed

Beams from the sources are alternatively stored in a damping ring (DR) reducing the emittances to the very low values required

Injection tracking with beam-beam

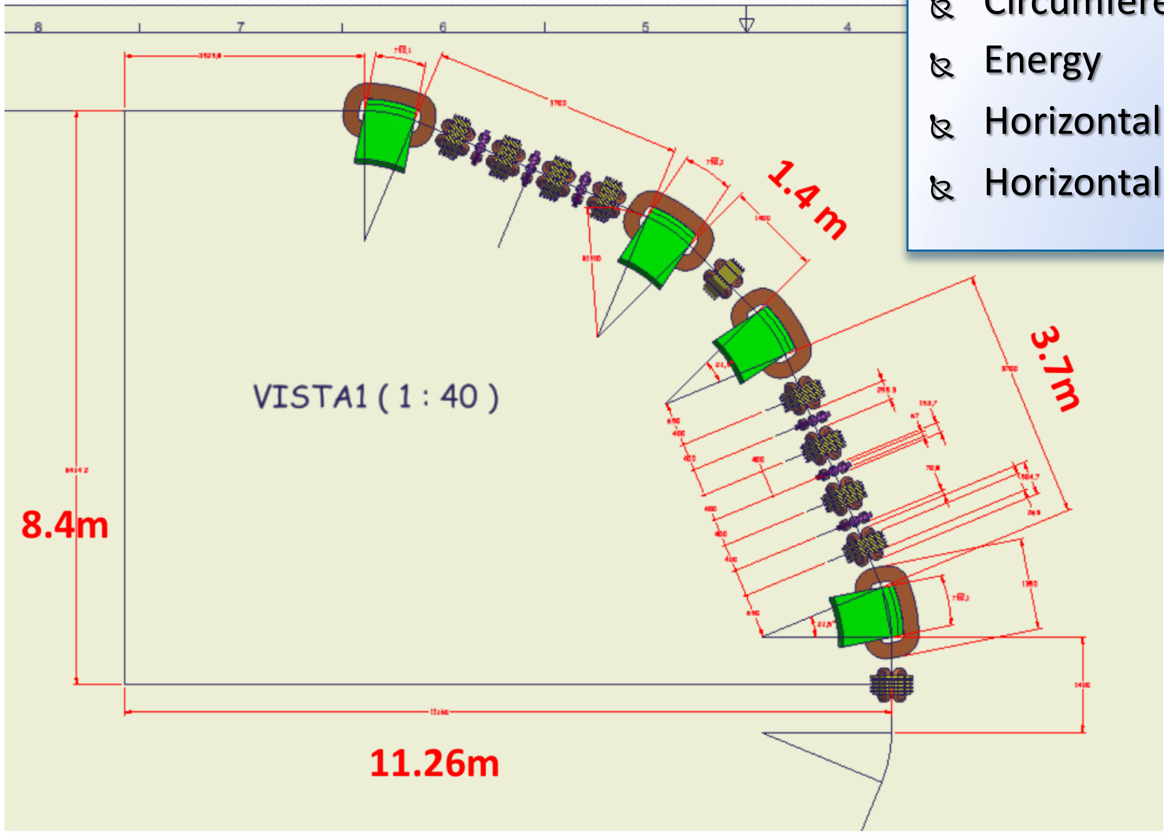


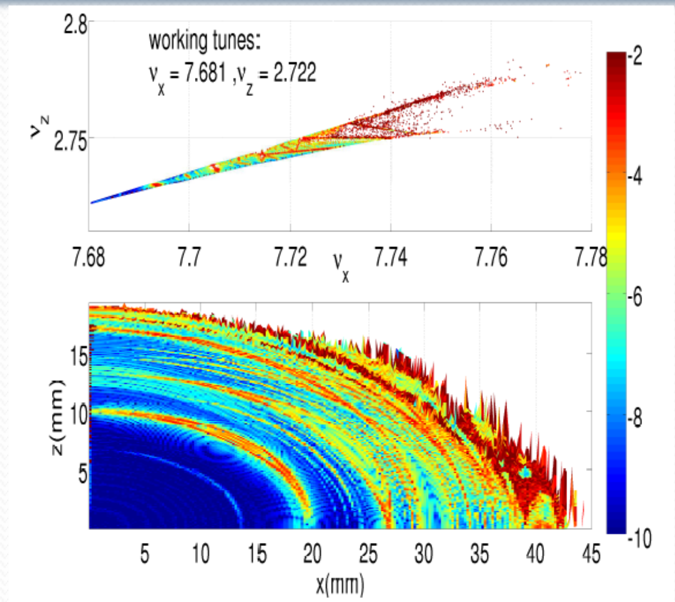
Contour plots of the injected beam distribution in the plane of normalized betatron amplitudes. 10^5 particles were tracked, and their coordinates over 100 consecutive turns were collected to build the distribution.

Shatilov

DR Status

- Circumference 51 m -> 66 m
- Energy 1 GeV -> 1.1 GeV
- Horizontal Emittance 23 nm > 33 nm
- Horizontal damping time 7.3 ms -> 8.0 ms



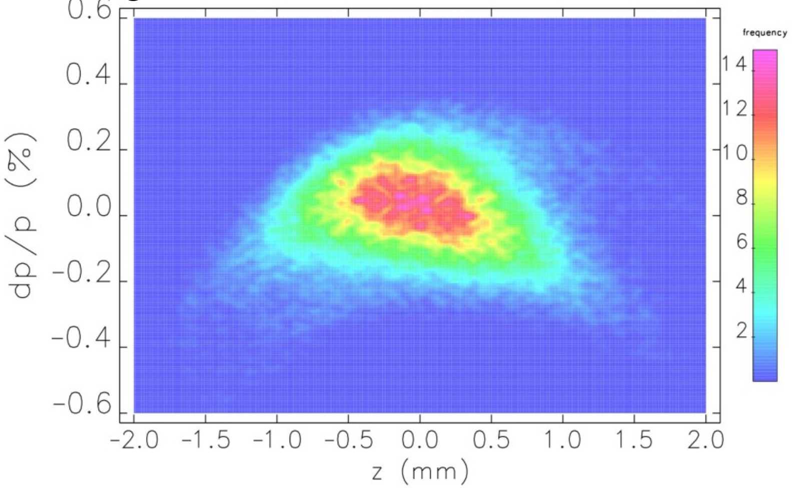


Drift spaces in the lattice have been modified to accommodate the real magnet dimensions as shown in the layout
The optical funtions are very similar to the old lattice

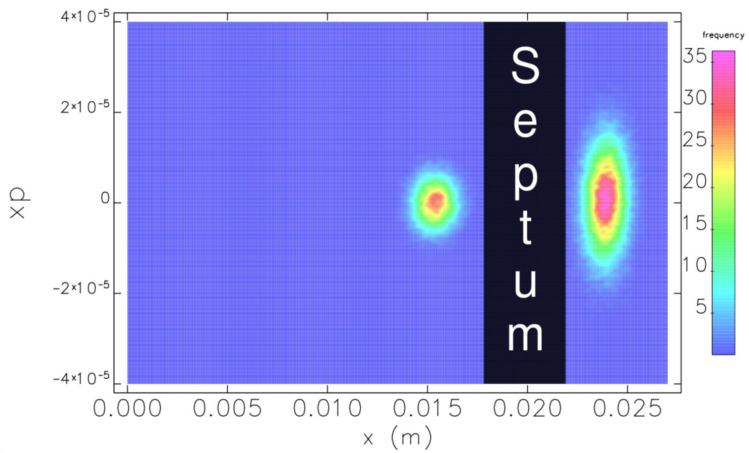
Jianfeng Zhang

Start to end simulation: DR to Main Ring

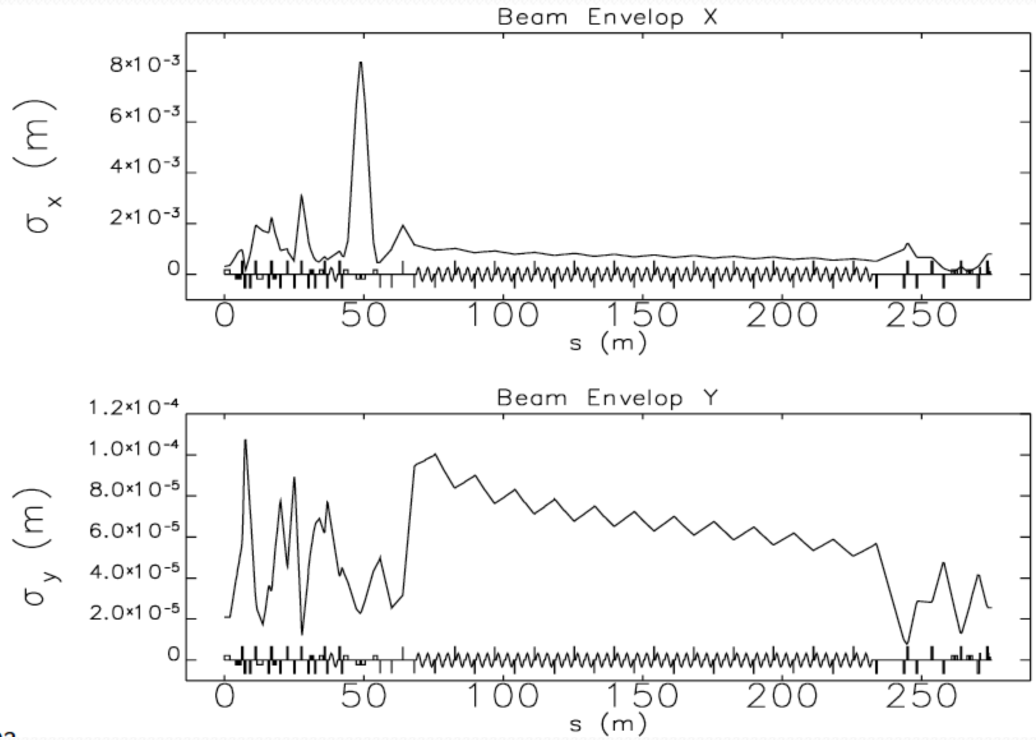
Long distribution after the linac - e-



x distribution at LER ring injection



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

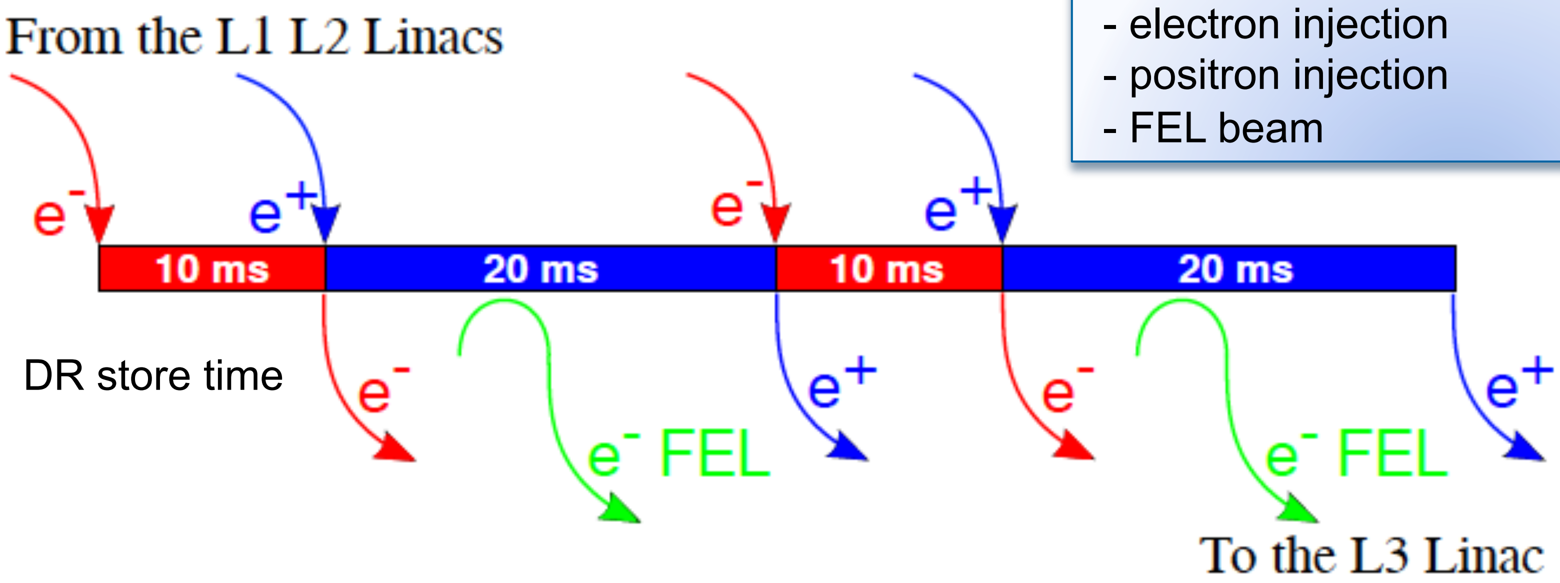


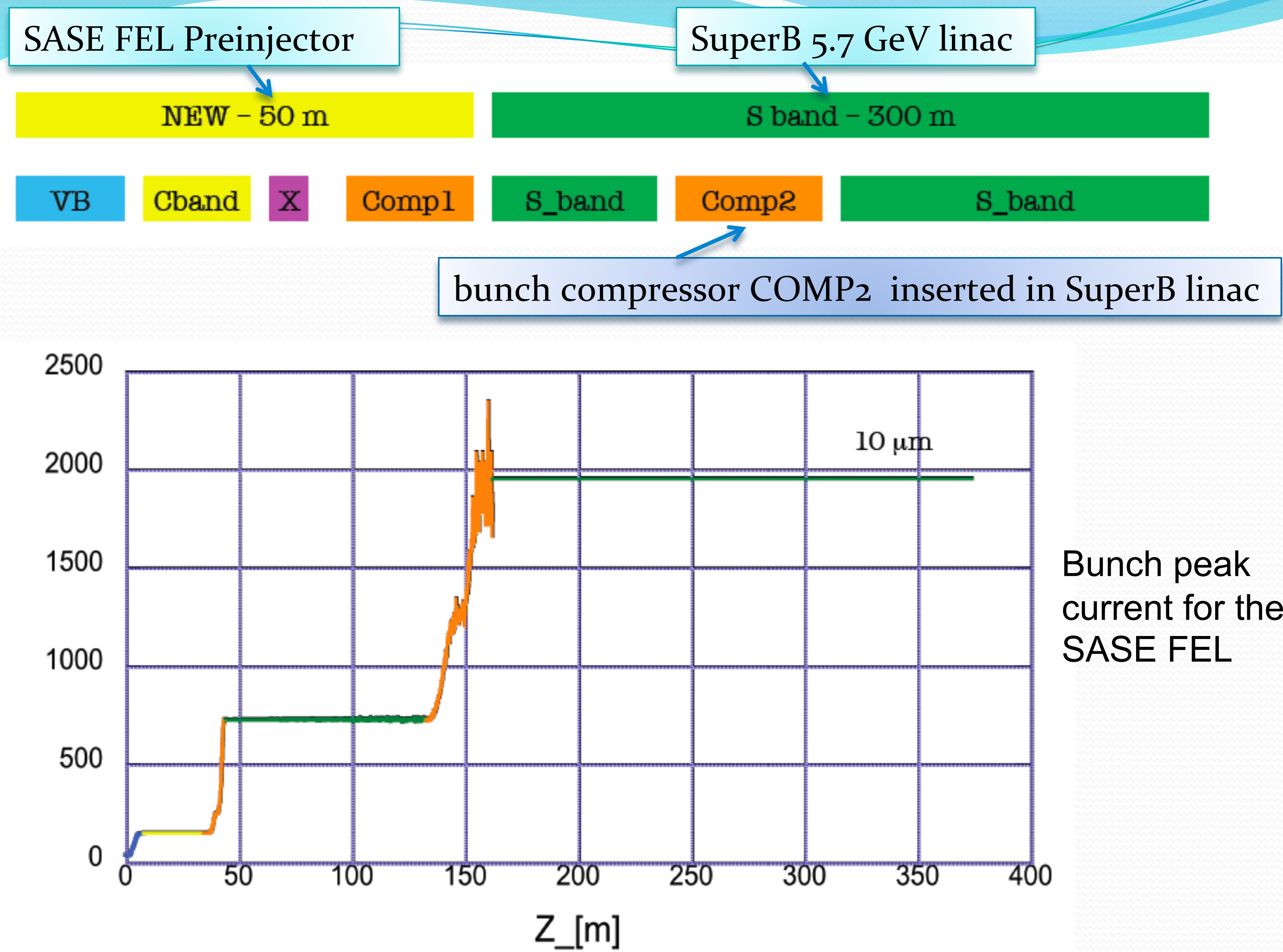
D.Pellegrini

SuperB as a SASE X-FEL

- The possibility to drive a SASE Hard-X FEL using the 6 GeV e⁻ linac has been recently considered
- 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
- 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





Bunch peak current for the SASE FEL

M. Ferrario

Costing Review

- Request to produce in a **very short delay** a preliminary costing based on the 'frozen' CDR design.
- A final document will soon be ready to be provided to the commission.
- At present we finalized the full WBS, the associated costing, the manpower requirements and its temporal profile.
- Cost Estimation → including personnel, spare components, contingency and VAT;
- Human Resources plan → including the identification of the detailed profiles for the first phase of the project to fulfill the 2013 milestones.
- Different scenarios are explored to provide a coherent plan for hiring, associating and organising the accelerator design team
- AT PRESENT THE NECESSARY EXPERTISE AND MANPOWER IS NOT YET AVAILABLE

Conclusions

- Cabibbo Lab in charge of construction and operation
- Management of Accelerator in place, hiring of some personnel in progress
- MOU with several international laboratories signed (BINP, Novosibirsk) or in preparation
- New full cost analysis ready for the costing commission
- Evaluation of the over-costing of the SASE configuration in progress
- At present our main goal is to produce a machine engineering footprint to allow the civil infrastructures to start
- A lot of work has been done but still we need manpower and missing expertise to provide a first acceptable footprint

Thanks to all the colleagues for the work
Thanks to M. E. Biagini and A. Variola for the slides

Thank you for your attention