The SuperB Accelerator

M. Boscolo

for the SuperB Accelerator Team

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The Superb Accelerator

- SuperB is a 2 rings, asymmetric energies (e^- @ 4.18, e^+ @ 6.7 GeV) collider with:
  - large Piwinski angle and "crab waist" (LPA & CW) collision scheme
  - ultra low emittance lattices
  - longitudinally polarized electron beam
  - target luminosity of 10^{36} cm^{-2} s^{-1} at the $\Upsilon(4S)$
  - possibility to run at τ/charm threshold with L = 10^{35} cm^{-2} s^{-1}

- Design criterias :
  - Minimize building costs
  - Minimize running costs (wall-plug power and water consumption)
  - Reuse of some PEP-II B-Factory hardware (magnets, RF)

- SuperB can also be a good "light source": work is in progress to design Sinchrotron Radiation beamlines (collaboration with Italian Institute of Technology)

Present status

- Physics case is fixed → main parameters (energies, injection rate, luminosity, polarization, …)
- Method for the luminosity increase is fixed (CW with large Piwinski parameter) →FF and IR design, emittance, …
- Tor Vergata site is fixed → footprint, configuration of injection facility, SR beam lines, etc.
- Low energy option at the tau threshold
- SR beamlines option is now in the layout

Parameter list

		Base Line		Low Emittance		High Current		τ/charm	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY (10^{36})	$cm^{-2}\ s^{-1}$	1		1		1		1	
Energy	GeV	6,7	4,18	6,7	4,18	6,7	4,18	2,58	1,61
Circumference	m	1195		1195		1195		1195	
X-Angle (full)	mrad	60		60		60		60	
Piwinski angle	rad	20,11	17,25	29,42	23,91	13,12	10,67	8,00	6,50
β_x @ IP	cm	2,6	3,2	2,6	3,2	5,06	6,22	6,76	8,32
β_y @ IP	cm	0,0253	0,0205	0,0179	0,0145	0,0292	0,0237	0,0658	0,0533
Coupling (full current)	%	0,25	0,25	0,25	0,25	0,5	0,5	0,25	0,25
ε_x (without IBS)	nm	2,00	1,7	1,00	0,91	1,97	1,82	1,97	1,82
ε_x (with IBS)	nm	2,14	2,363	1,00	1,23	2,00	2,46	5,20	6,4
ε_y	pm	5,35	5,9075	2,5	3,075	10	12,3	13	16
σ_x @ IP	μm	7,459	8,696	5,099	6,274	10,060	12,370	18,749	23,076
σ_y @ IP	μm	0,037	0,035	0,021	0,021	0,054	0,054	0,092	0,092
Σ_x	μm	11,457		8,085		15,944		29,732	
Σ_y	μm	0,051		0,030		0,076		0,131	
σ_L (0 current)	mm	4,69	4,29	4,73	4,34	4,03	3,65	4,75	4,36
σ_L (full current)	mm	5	5	5	5	4,4	4,4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Buckets distance	ns	4,20		4,20		2,10		2,10	
Ion gap	%	2		2		2		2	
RF frequency	MHz	476		476		476		476	
Harmonic number		1998		1998		1998		1998	
Number of bunches		442		442		884		884	
N. Particle/bunch (10^{10})		5,08	6,56	3,92	5,06	4,15	5,36	1,83	2,37
Tune shift x		0,0026	0,0040	0,0020	0,0031	0,0053	0,0081	0,0063	0,0096
Tune shift y		0,1089	0,1033	0,0980	0,0981	0,0752	0,0755	0,1000	0,1001
Long. damping time	msec	13	18,0	13,4	20,3	13,4	20,3	26,8	40,6
Energy Loss/turn	MeV	2,11	0,865	2,11	0,865	2,11	0,865	0,4	0,166
σ_E (zero current)	δE/E	6,10E-04	7,00E-04	6,43E-04	7,34E-04	6,43E-04	7,34E-04	6,94E-04	7,34E-04
σ_E (with IBS)	δE/E	6,28E-04	7,91E-04						
CM σ_E	δE/E	4,75E-04		5,00E-04		5,00E-04		5,26E-04	
Total lifetime	min	4,23	4,48	3,05	3,00	7,08	7,73	11,41	6,79
Total RF Power	MW	16,38		12,37		28,82		2,81	

Baseline + other 2 options:
- **Lower y-emittance**
- **Higher currents (twice bunches)**

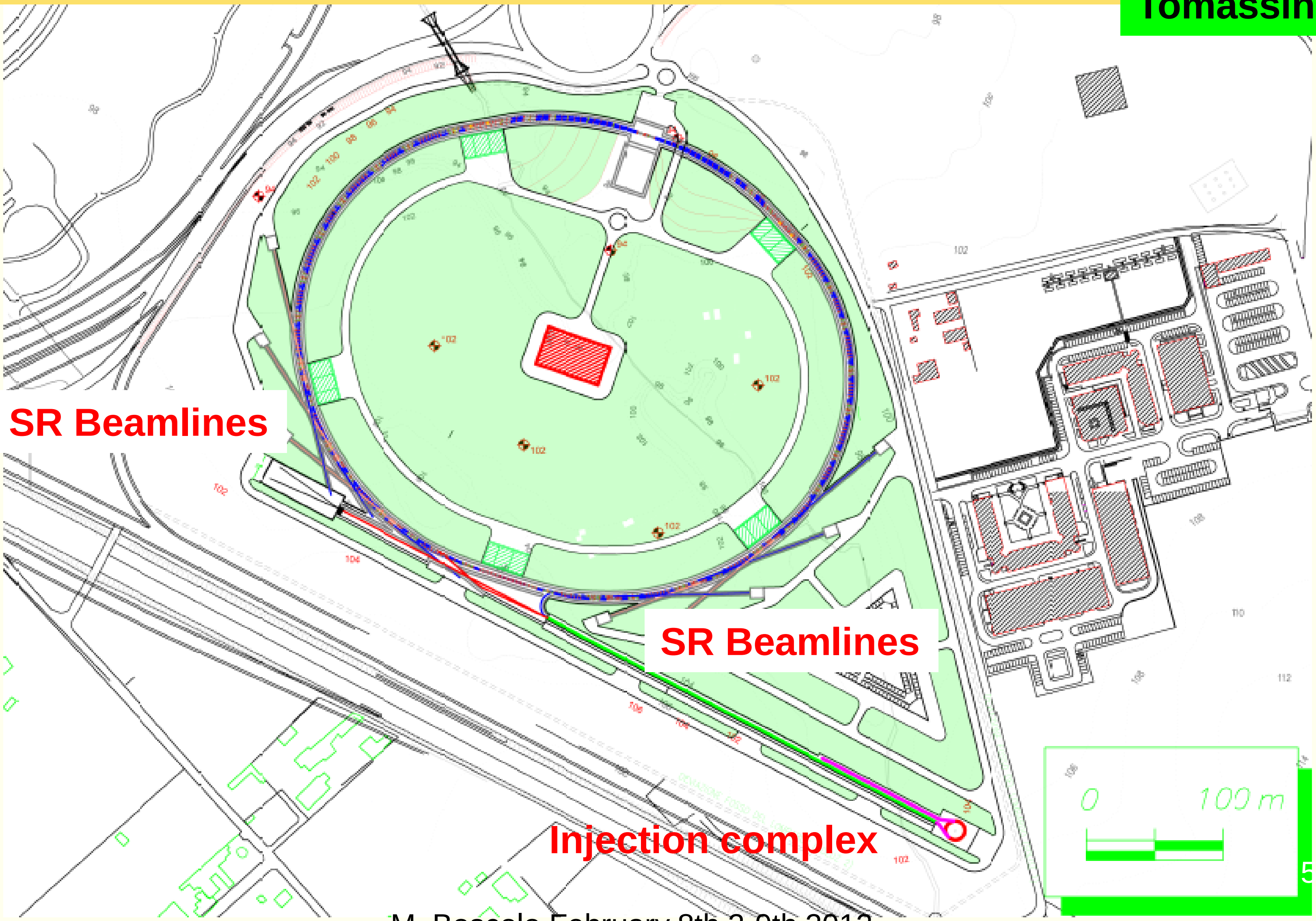
Baseline:
- **Higher emittance due to IBS**
- **Asymmetric beam currents**

RF power includes SR and HOM

Tau/charm threshold

SuperB @ Tor Vergata

Tomassini




Site under study
About 4.5 Km
LNF
Via di Passolombardo
SP77b
SS215
A1 dir
© 2011 Tele Atlas
Image © 2011 DigitalGlobe

Ground motion measurements at Tor Vergata

B. Bolzon[1], G. Deleglise[2], A. Jeremie[2], S. Tomassini[3]

Experimental setup

Accelerometer on the hard shoulder of the highway

Accelerometer below the bridge on a rigid floor

Accelerometer below the soft bank on the soft floor

✓ Evaluation of the damping factor of vibrations between:

- ➢ The hard shoulder of the highway and the soft floor below the bank
- ➢ The hard shoulder of the highway and the rigid floor below the bridge

➔ Goal: to show that the measured low vibrations of the Tor Vergata site are due to the very good properties of its floor (soft floor)

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Conclusions on Ground motion measurements at Tor Vergata

B. Bolzon[1], G. Deleglise[2], A. Jeremie[2], S. Tomassini[3]

- ✓ Main source of vibrations of Tor Vergata Site: the highway
- ✓ However, vibrations well damped near the highway (just below the bank) thanks to the very soft floor of this site
- ✓ Moreover, the Super B will be built at a minimum of 100m from the highway where vibrations are very low

  ➔ In the 3 axes: Amplitude varies from 8nm to 30nm for all the points above 1Hz (and from 30nm to 60nm above 0.2Hz)

  ➔ For the interaction point: a road is planned to be made soon near this point but since there is also a high bank, vibrations should be well damped

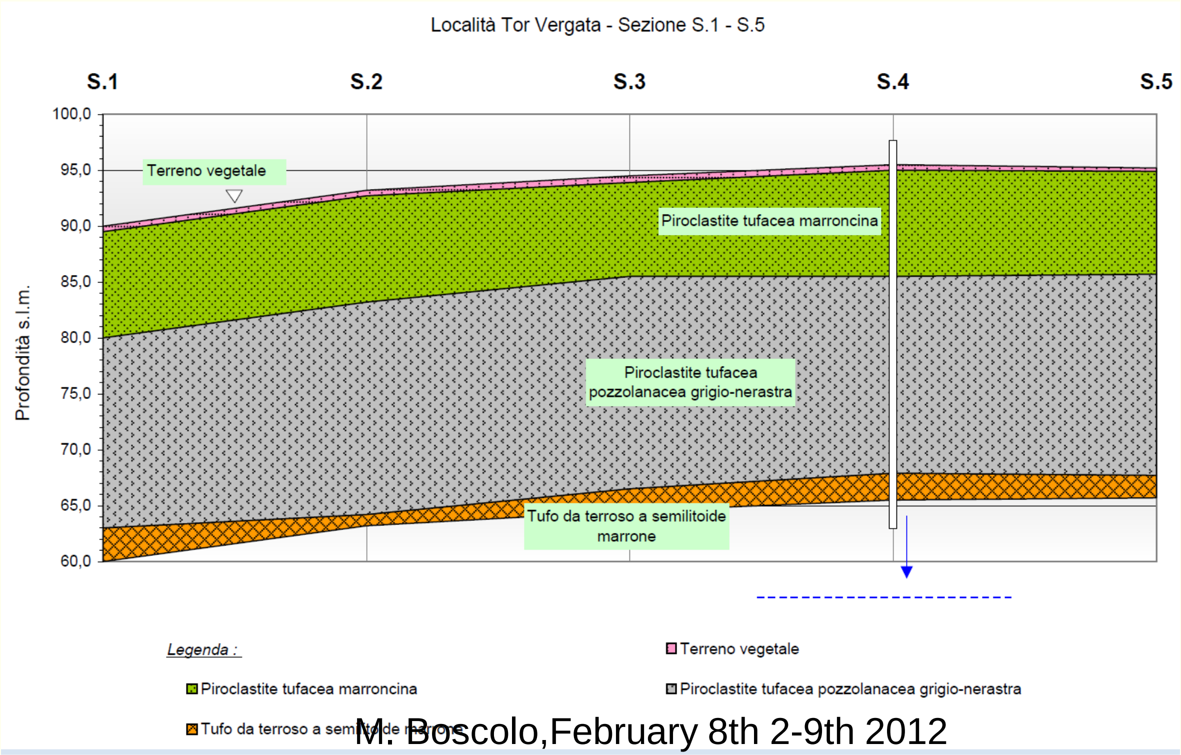
- ➢ INFN site: too close to main roads and the floor does not damp vibrations like it does at the Tor Vergata site

  ➔ Vibrations can be huge in the INFN site during the day and especially during traffic time contrary to the Tor Vergata site

➔ Tor Vergata seems to be a very good site for the Super B project compared to the INFN site where the only choice is to build a tunnel in underground

Ground measurements

- Ground motion measurements performed on site in April 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

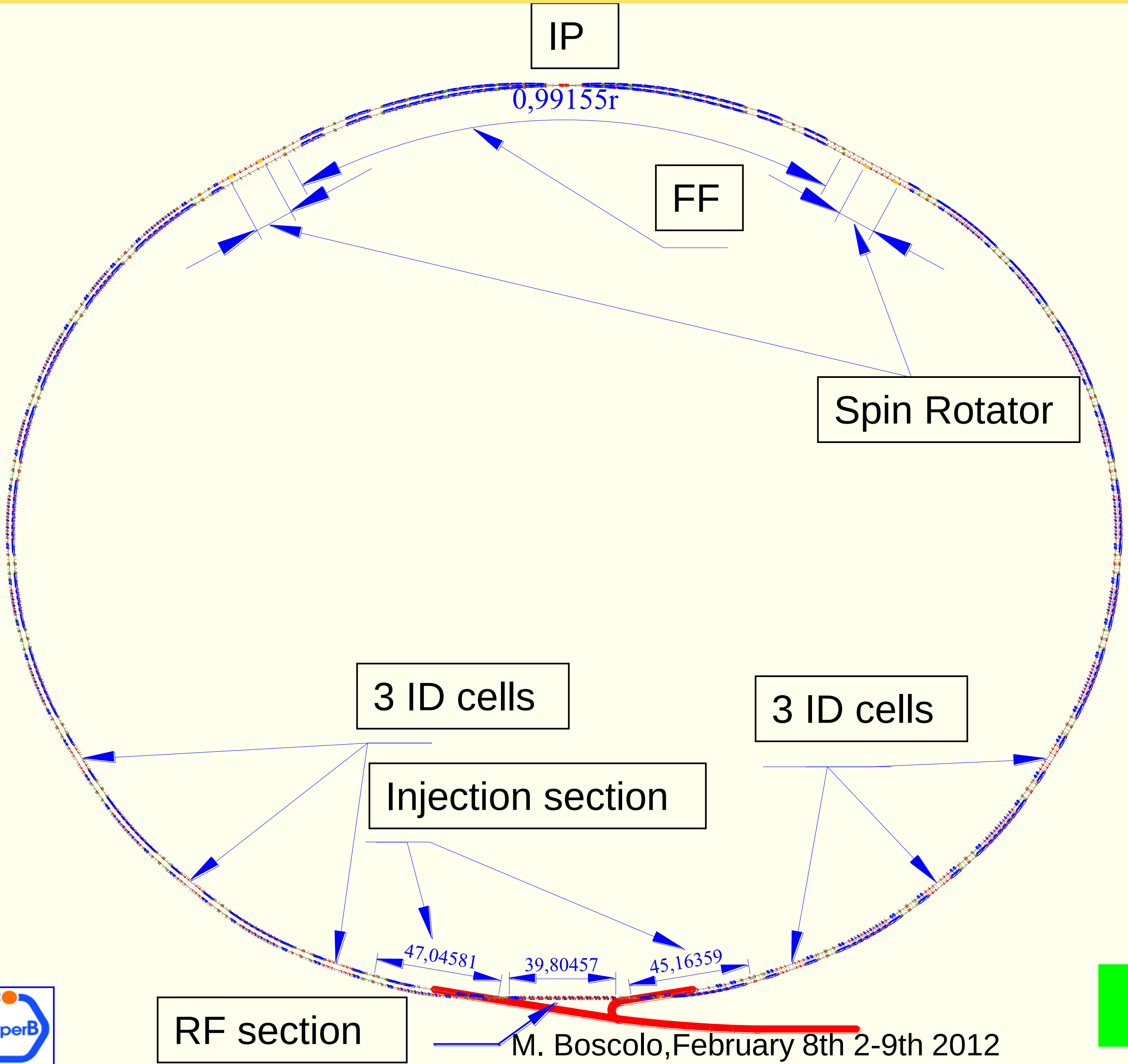


Ground x-section Volcanic soil

Rings Lattice

- 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
- In the latest version of the lattice some cells for Insertion Devices have been inserted
- Rings are hosted in the same tunnel, separated about 2 m in horizontal and 1 m in vertical (opposite to IP)

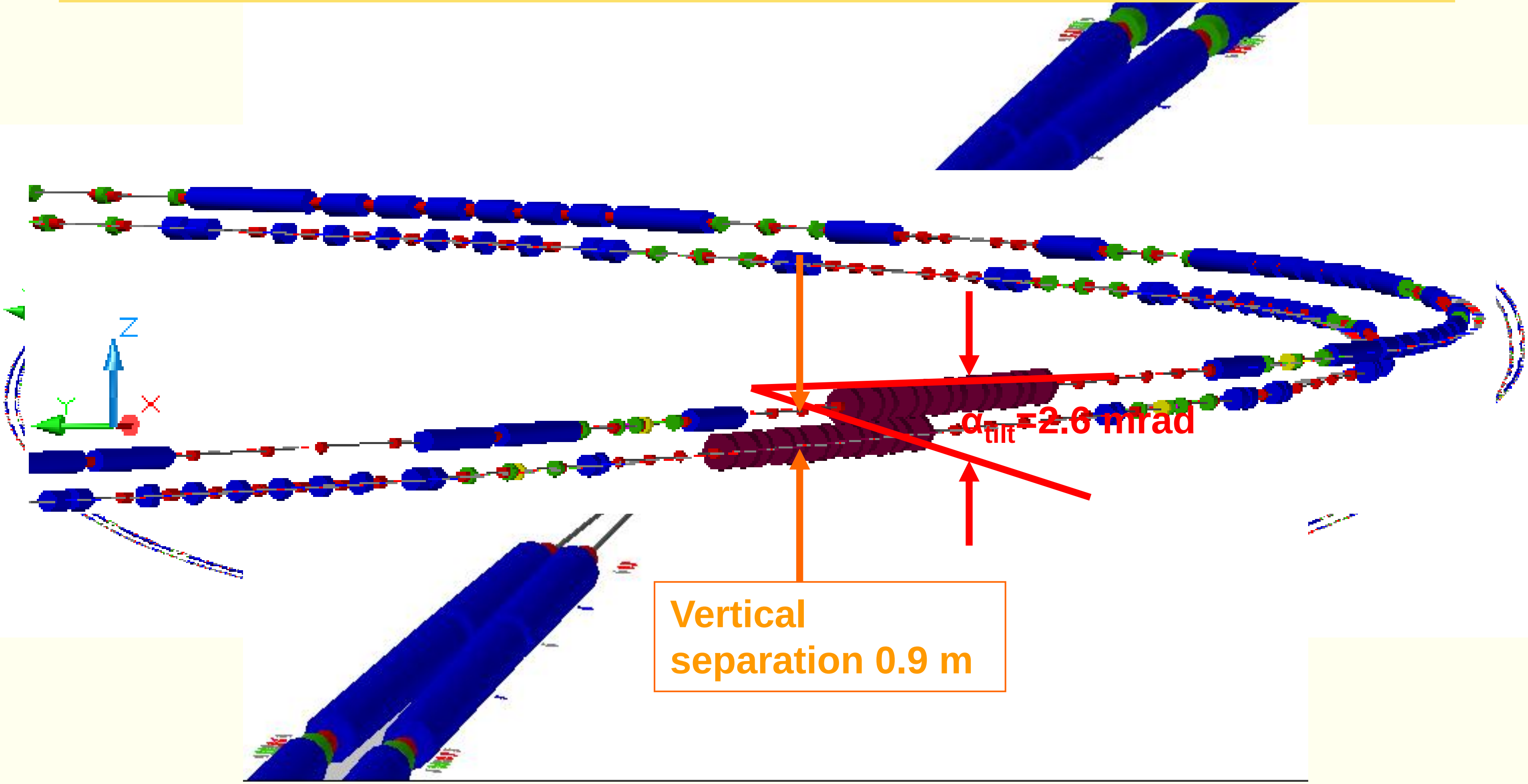
Collider Layout



- Circumference 1195 m
- Horizontal separation of arc ~2 m
- Vertical separation of RF section 0.9 m
- Dimension sizes of rings 416 m x 342 m

Siniatkyn

Vertical rings separation



Rings tilt at IP can provide ~1 m vertical separation at the opposite point:
(a) e+e- beams separation, (b) SR beamlines from both rings, (c) better equipment adjustment

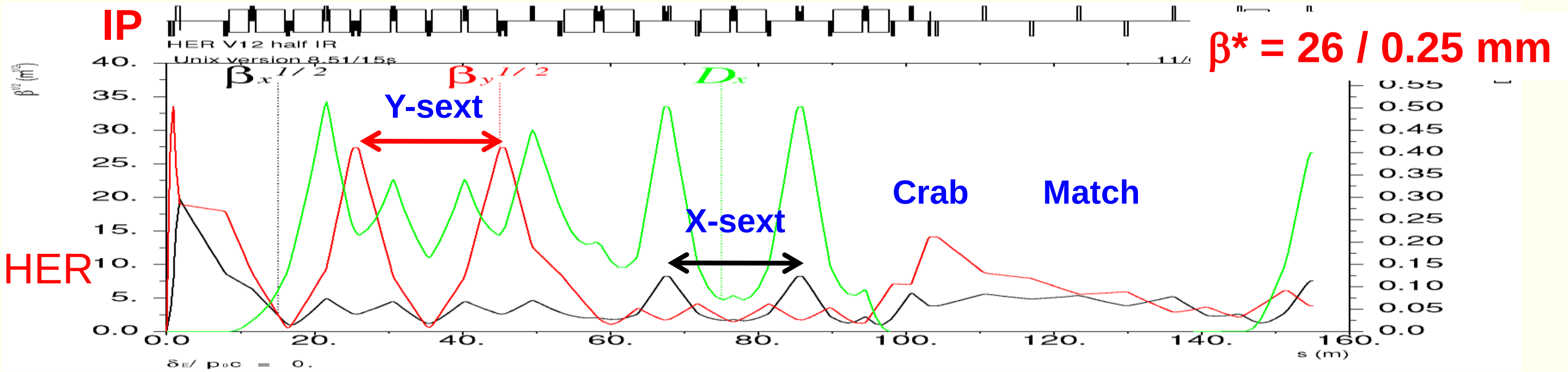
IR design

- We have two designs that are flexible and have good:
  - SR backgrounds
  - Lattice functions
  - Beam apertures
- These designs greatly improve the lattice and energy flexibility of the overall IR design. IP doublets options:
  - Vanadium Permendur for QD0 and QF1 (prototype in progress @ BINP)
  - Parallel air-core dual quads for QD0 and QF1 (prototype in progress @ Genova)
    - Both designs include additional vanadium permendur Panofsky quads on the HER
- We have a scheme for correcting the coupling induced by the detector solenoid and we know also how to run the machine without the detector solenoid

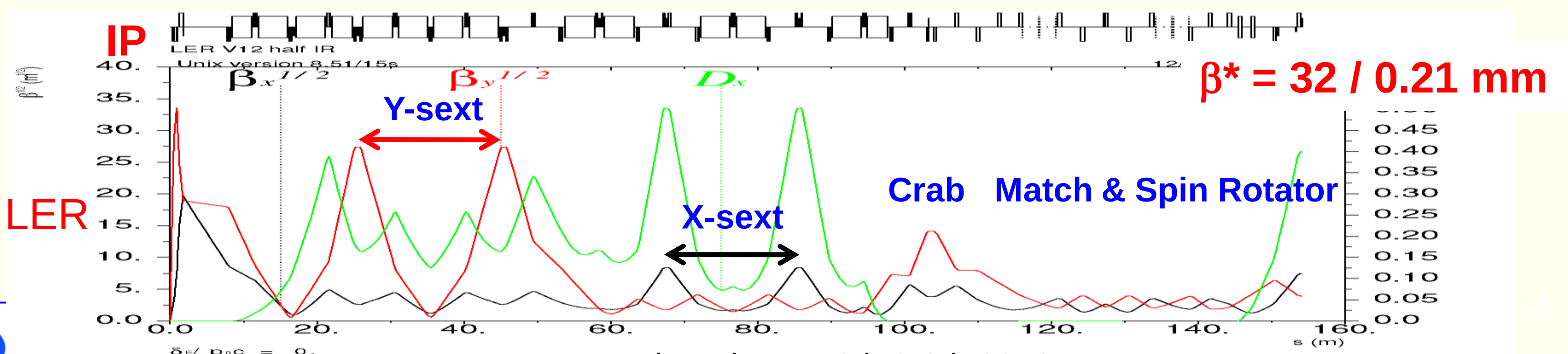
M.Sullivan

Final Focus sections

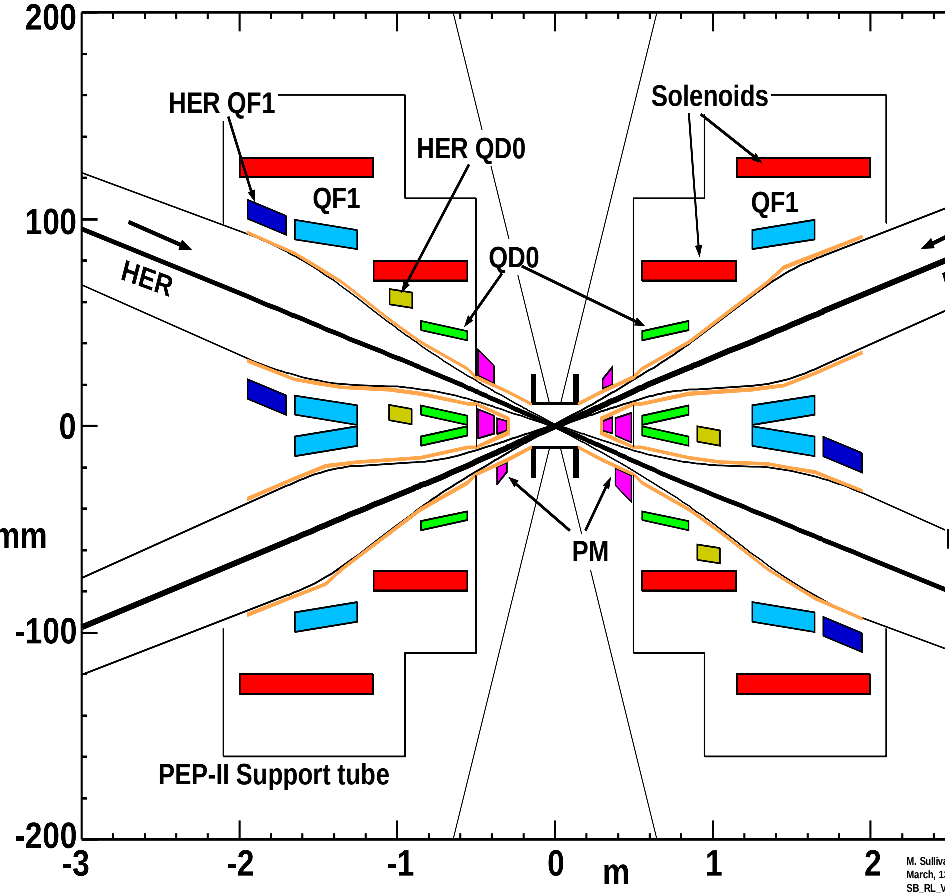
“Spin rotator” optics is replaced with a simpler matching section

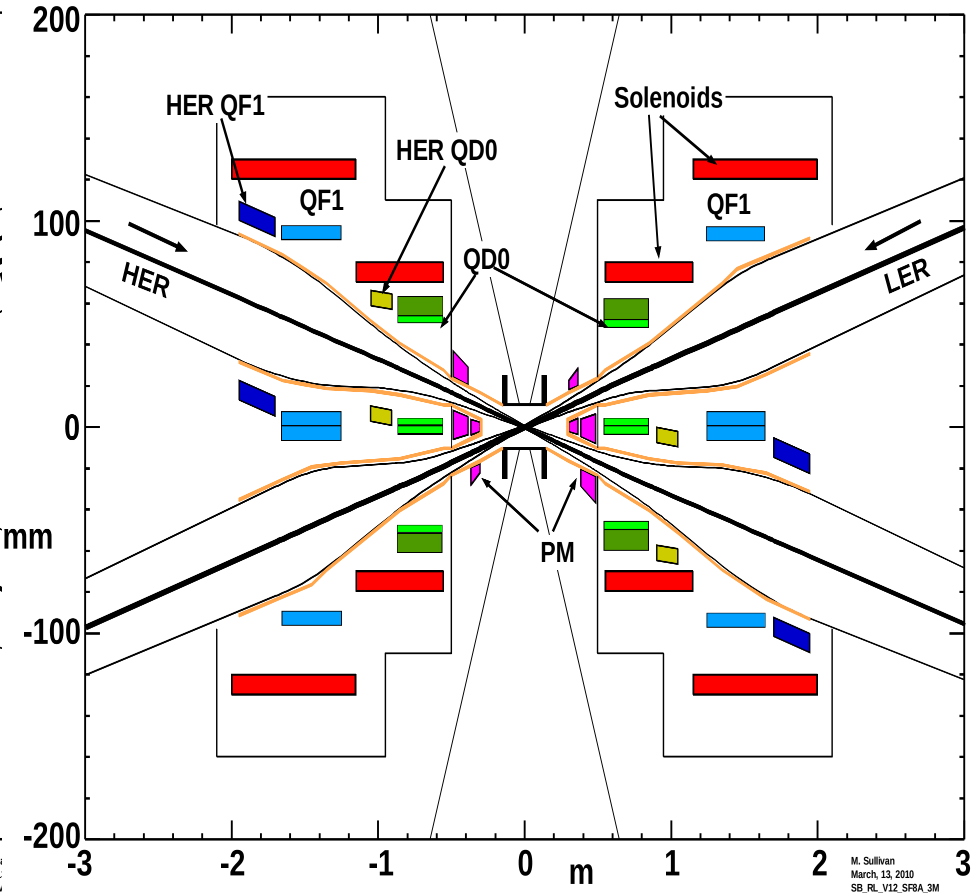


Matching section is shorter than HER to provide space for spin rotator optics.
±30 mrad bending asymmetry with respect to IP causes a slight spin mismatch between SR and IP resulting in ~5% polarization reduction.



QD0 Design: 2 possible choices





Vanadium Permendur "Russian" Design

Air core "Italian" QD0, QF1 Design

More in dedicated talks!

QD0 DESIGN OPTIONS

"Italian" Design

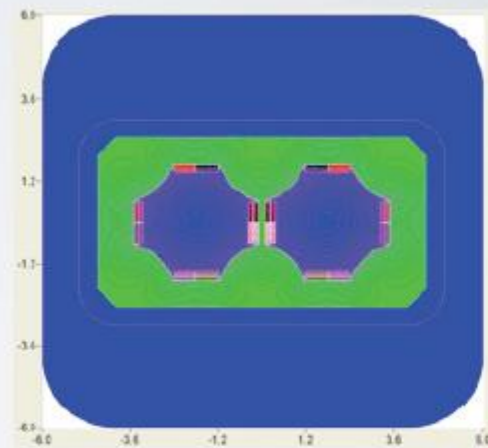
Field generated by 2 double helix windings in a grooved Al support

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

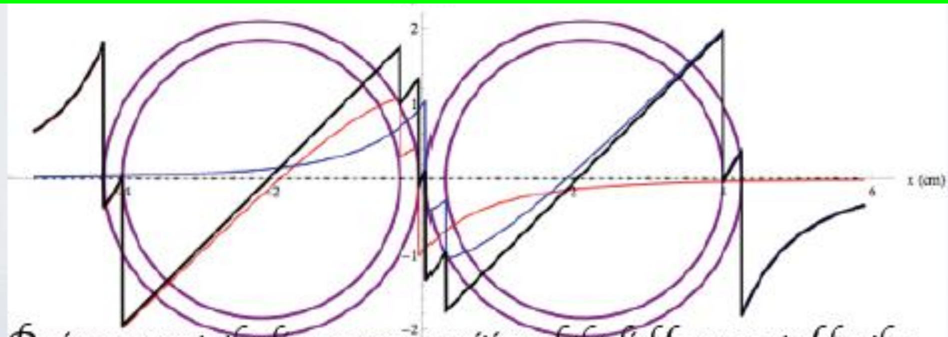
Conceptual sketch

"Russian" Design

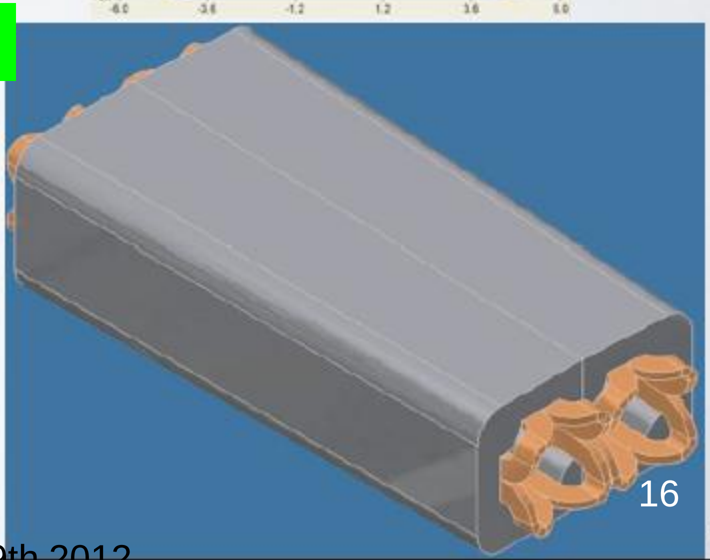
I. Okunev, V. Syrovatin, A. Bragin, P. Vobly



Air-core QD0 is a SC iron free septum double quad

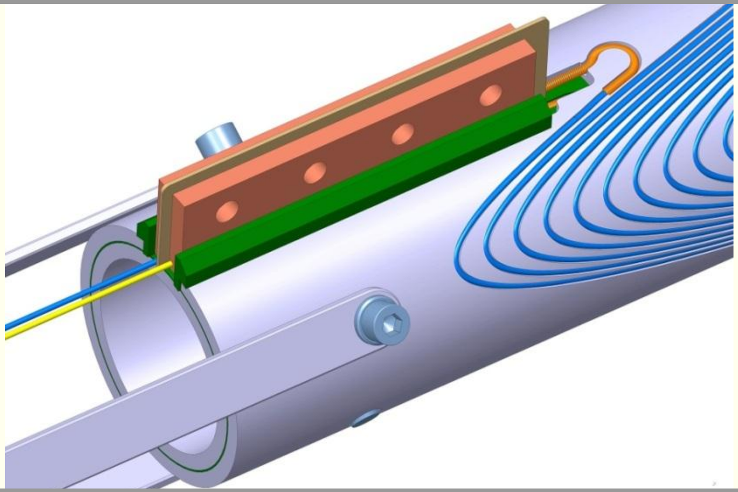


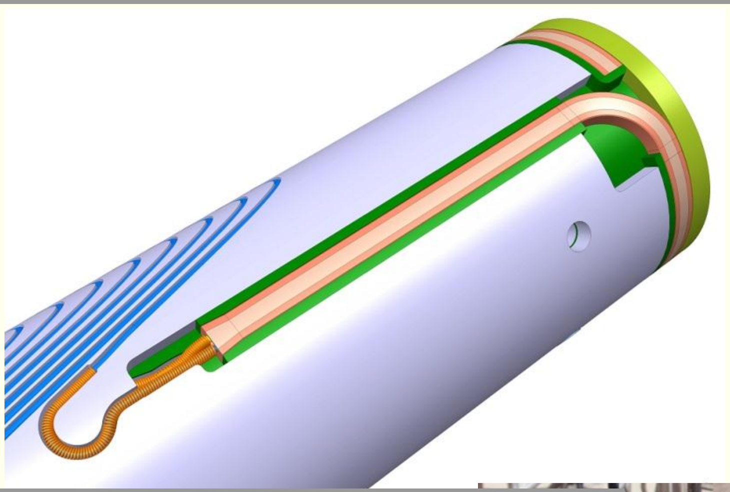
Design concept: the linear superposition of the fields generated by the left coil (in red) and by the right one (in blue) produces the needed quadrupolar field (in black).



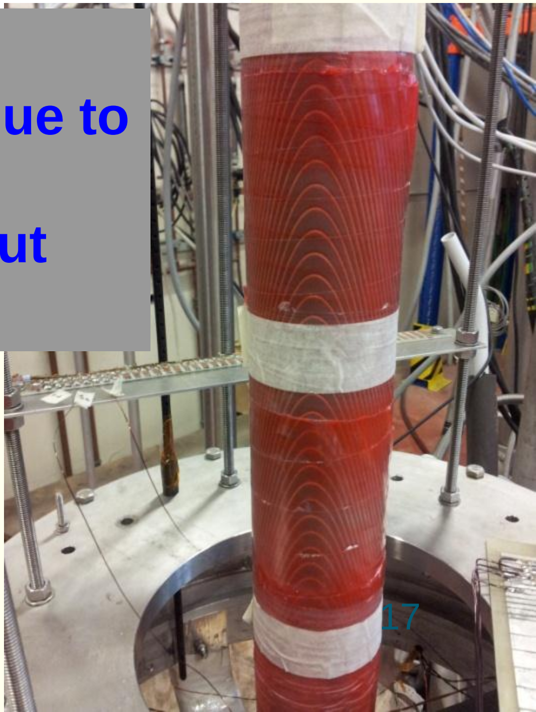
Construction of a model coil to address quench issues

The coil has been constructed at ASG Superconductors and now is at INFN Genova for testing at 4.2K. The results of this test are crucial for the design.





Successfully powered up to 2750A @4.2K (100 A more than design). Quenches start at 2350A due to some mechanical disturbance.
Magnet survives well to multiple quences even without protection!



Collettive effects

Stored beams are subject to effects that can produce instabilities or degrade the beam quality, such as:

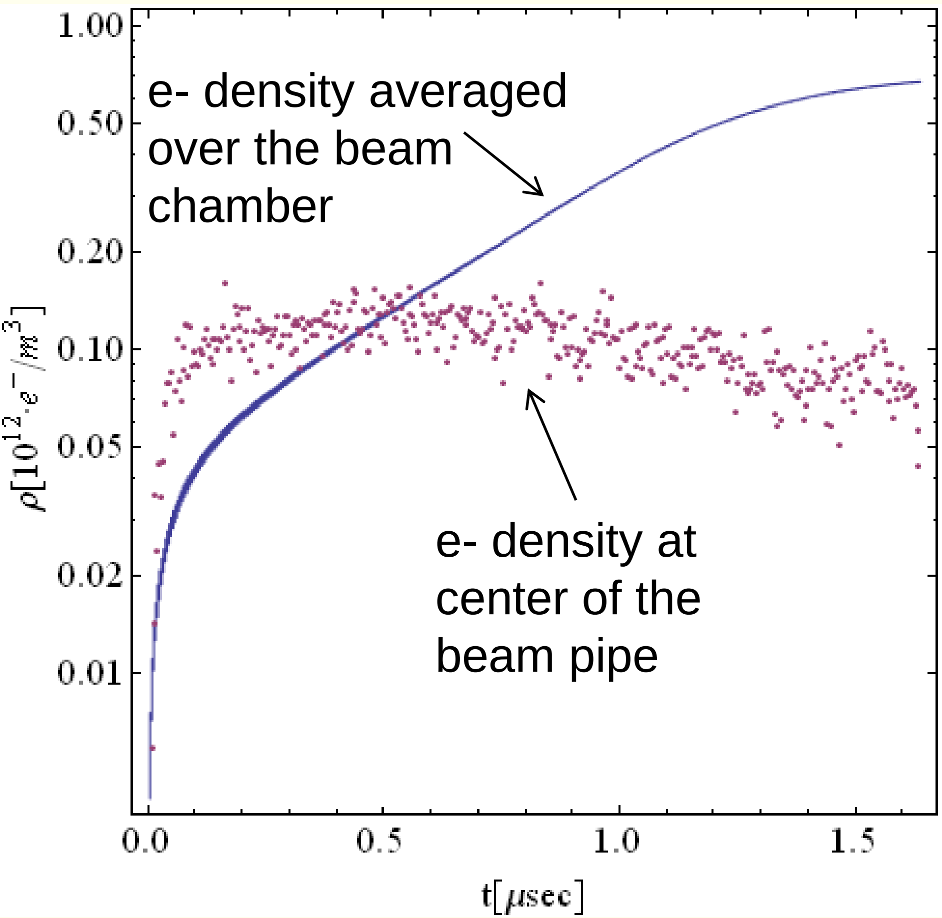
- Intra-Beam-Scattering (IBS) inside the bunch produces emittance and energy spread growth (not important in Damping Ring)
- Electron-cloud instability limits the current threshold of the positron beam → needs mitigation methods (ex. solenoids, beam pipe coating, clearing electrodes...)
- Fast Ions Instability is critical for the electron beam
- CSR (Coherent Synchrotron Radiation) degrades beam quality (not important in Damping Ring)

Most of these effects have been studied and remediation techniques chosen

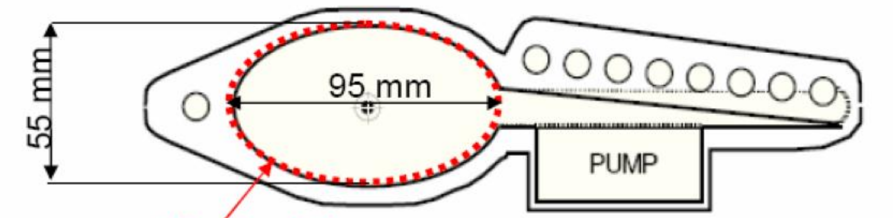
e-cloud buildup in HER Dipoles

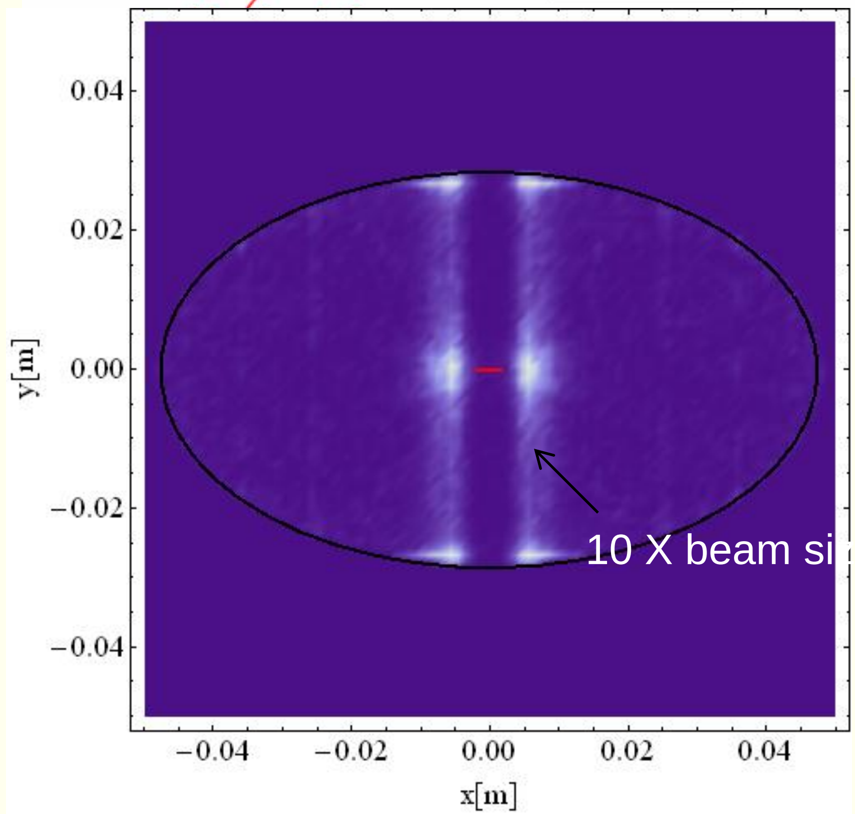
Demma

By=0.3 T; η=95% SEY=1.1



LER dipole vacuum chamber (CDR)

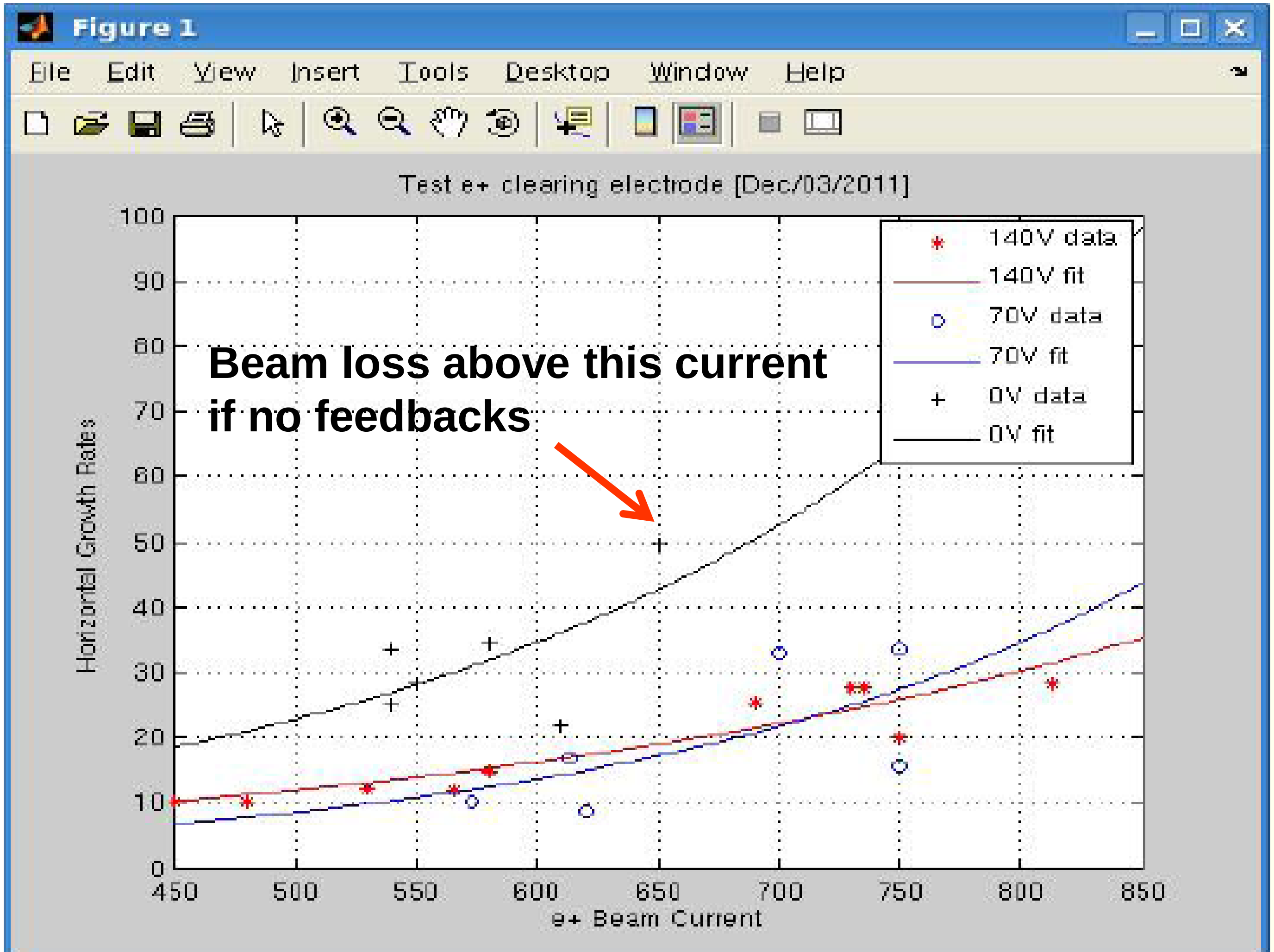




e-cloud clearing electrodes in DAΦNE

Drago

Horizontal growth rate measurements

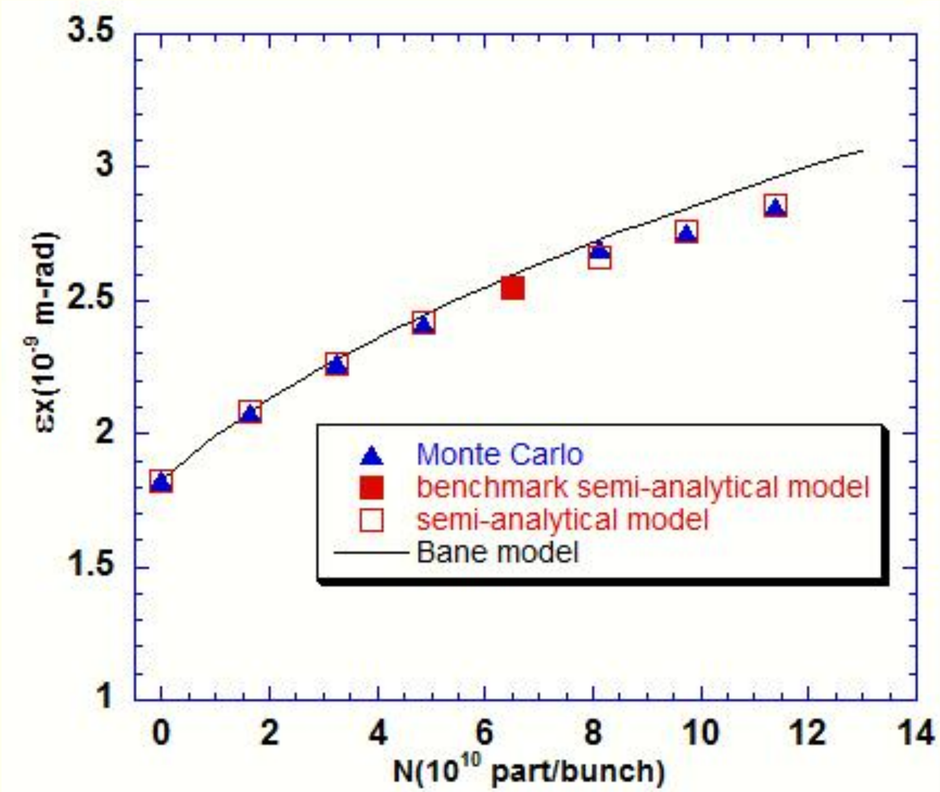


Very positive results: vertical beam dimension, tune shift and growth rates clearly indicate the good behaviour of these devices, which are complementary to solenoidal windings in field free regions

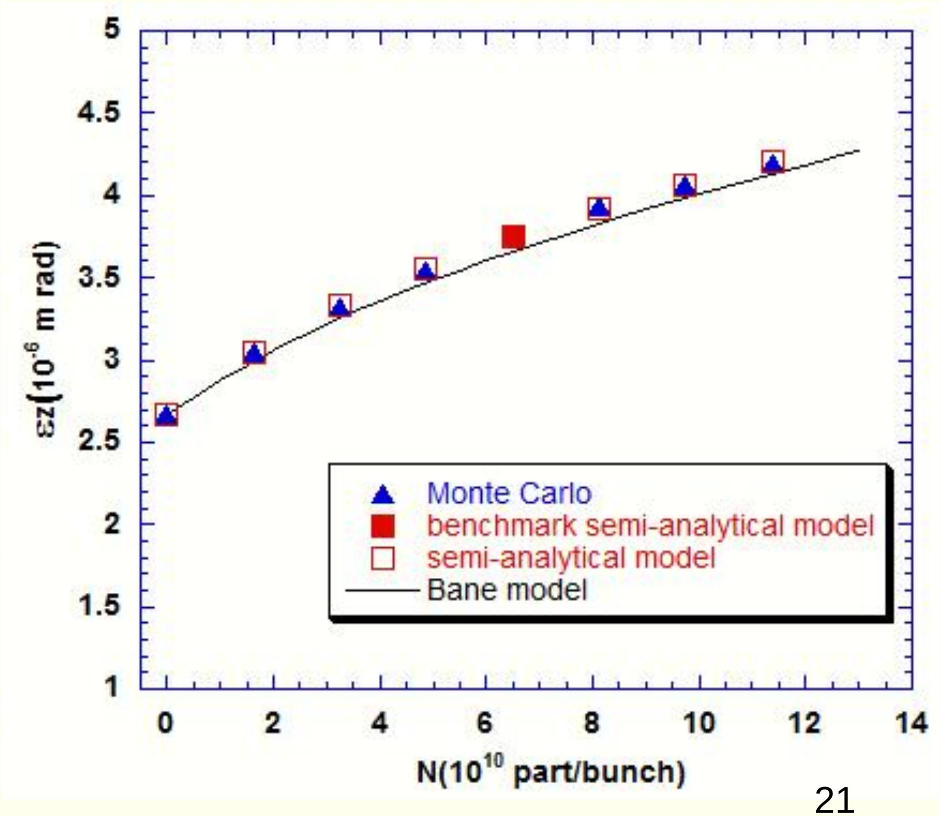
IBS @LER SuperB

M. Boscolo, A.Chao,Demma

Equilibrium horizontal emittance vs bunch current

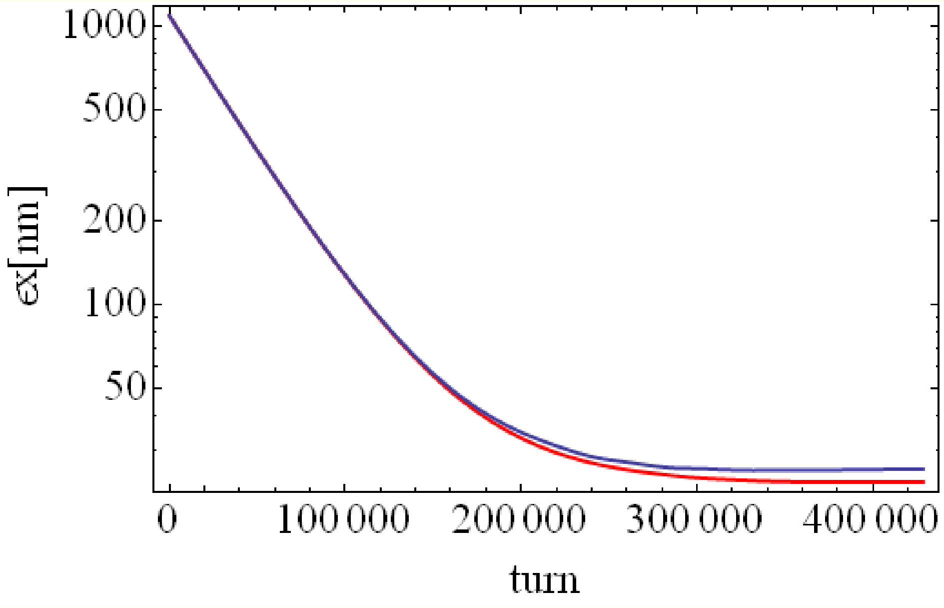


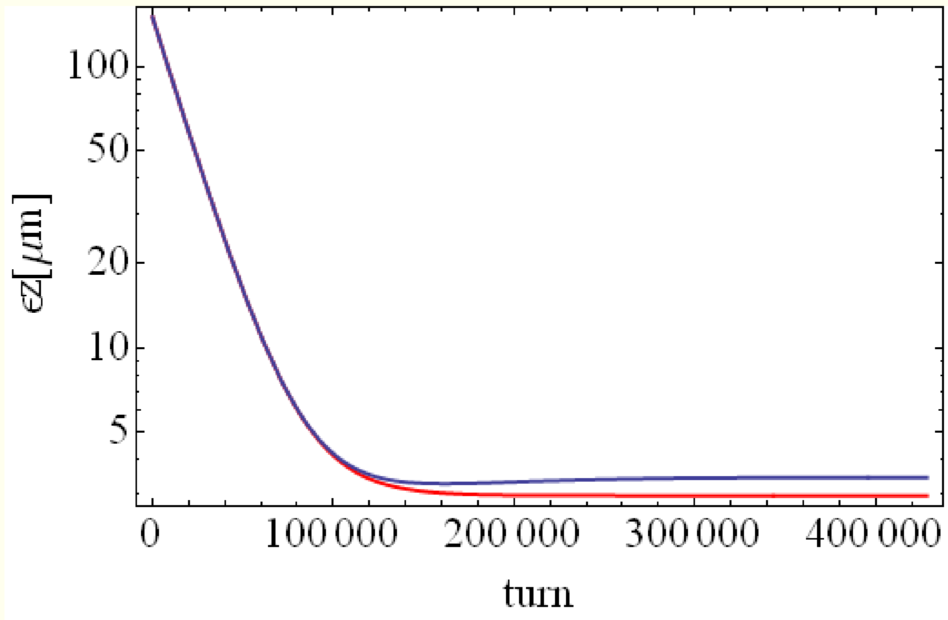
Equilibrium longitudinal emittance vs bunch current



IBS in Damping Ring

Demma





	ε_x (m)	ε_z (m)
Injection	1100e-9	1.5e-4
Extraction w/ IBS	25e-9	3.3e-6
Extraction w/o IBS	23e-9	2.97e-6

Radiation Damping + Quantum Excitation

Radiation Damping + Quantum Excitation + IBS

Effect of IBS on the damping process is very small

CSR in Damping Ring

Zhou

TABLE II. Estimated instability threshold for SuperB and SuperKEKB positron damping rings

	SuperB	SuperKEKB
Design	0.4×10^{10}	1.3×10^{10}
N_{th2}	1.19×10^{10}	4.6×10^{10}
N_{th3}	1.17×10^{10}	4.4×10^{10}

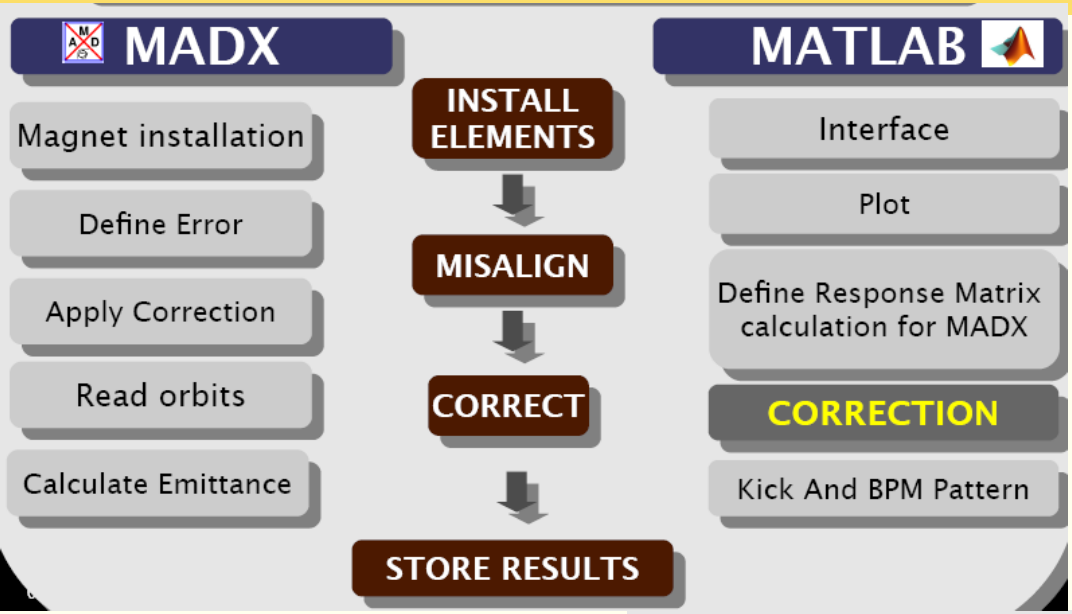
For both SuperB and SuperKEKB Coherent Synchrotron radiation instability is not a problem in topping up mode, threshold being about 3 times the bunch population

Low emittance tuning

Liuzzo

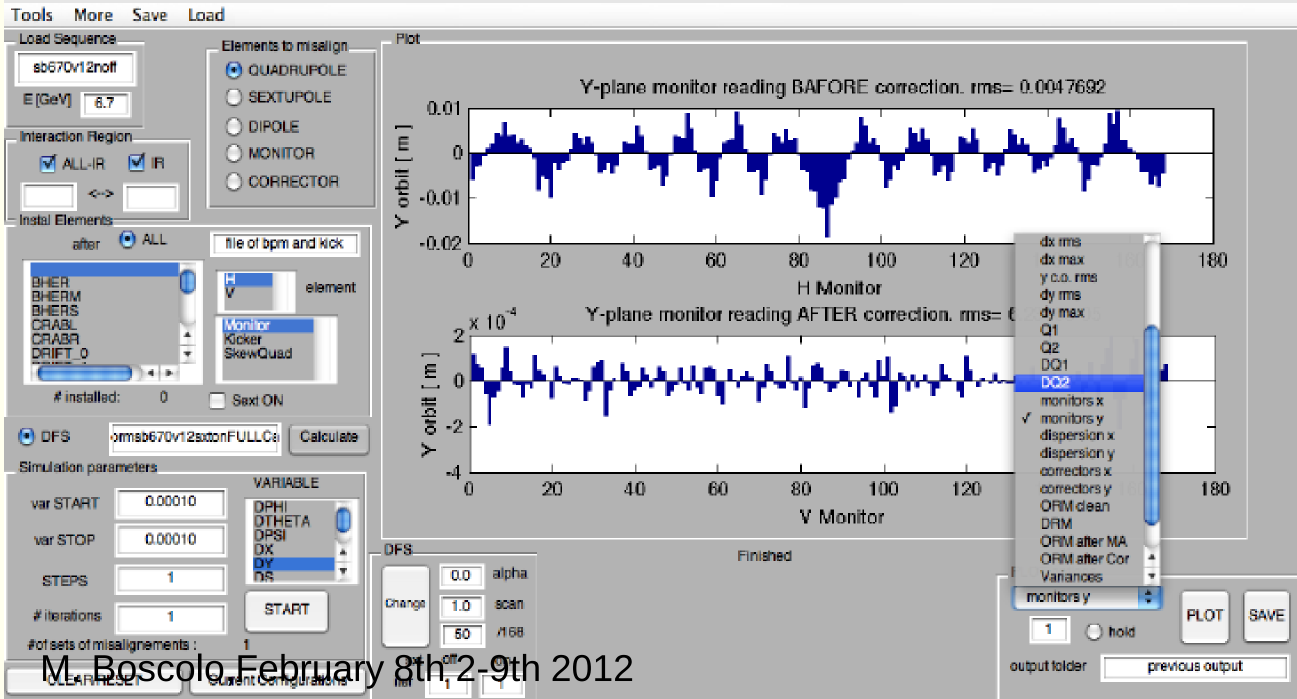
- The extremely low design beam emittance needs to be tuned and minimized → careful correction of the magnet alignment and field errors
- These errors produce emittance coupling with transfer of some horizontal emittance to the vertical plane → this needs to be minimized
- Beta-beating (ring β-functions are not as in the model machine, but are perturbed by the magnet errors) also needs minimization
- Vertical dispersion at IP needs to be corrected to the lowest possible value not to compromise luminosity

LET Tool



This tool has been successfully tested at Diamond (RAL) and SLS (PSI) synchrotron light sources, which have similar emittances as SuperB.

This work allows to set tolerances on magnet alignment and once the machine is running is able to detect such errors for correction

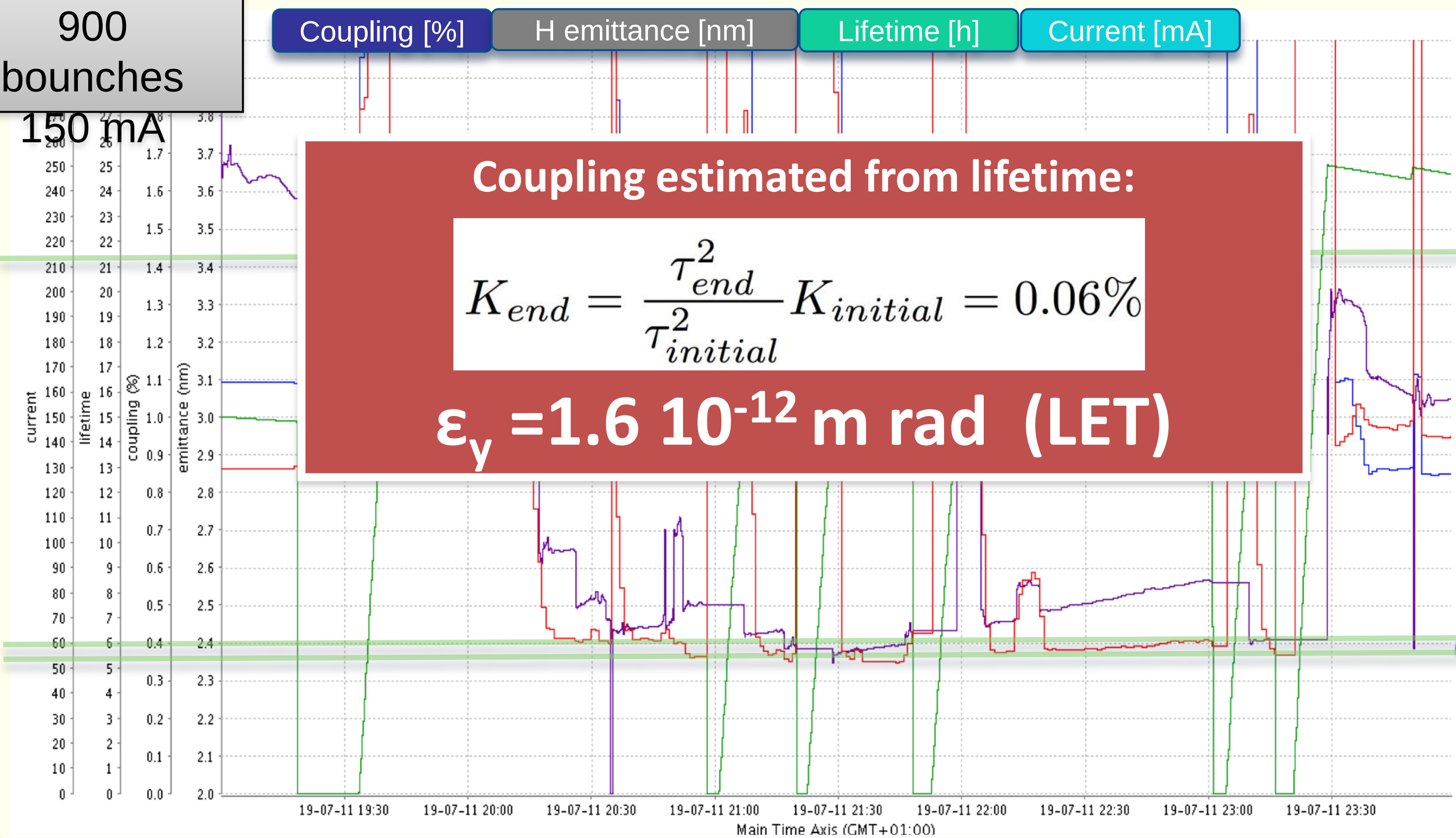


Measurements at Diamond

Liuzzo

Comparison between LET and LOCO

Decay mode
900 bounches
150 mA



Coupling estimated from lifetime:

$$K_{end} = \frac{\tau_{end}^2}{\tau_{initial}^2} K_{initial} = 0.06\%$$

$\varepsilon_y = 1.6\ 10^{-12}$ **m rad (LET)**

Initial conditions
21.1 h

After 2 LOCO iterations with **skew quad and quad**

5.9 h

5.5 h

After 4 LET iterations with **skew quad**

LOCO

LET

LOCO

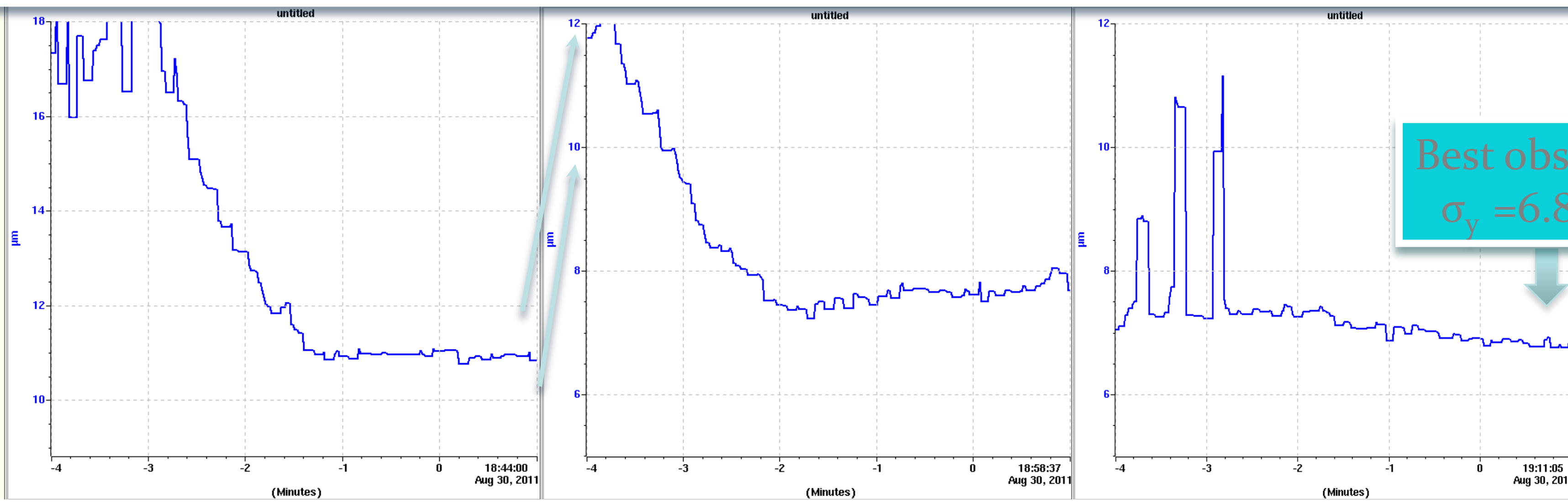
Final Lifetime measurements preformed after injection

BPM Tilt estimate by LOCO

Measurements at SLS

Top-up mode
400 mA
Normal user operations

Beam size measurement for 3 subsequent correction performed using only
VERTICAL STEERERS



Best observed
σ_y =6.8 μm

SLS best σ_y = 4.9 μm is obtianed using skew quadrupoles

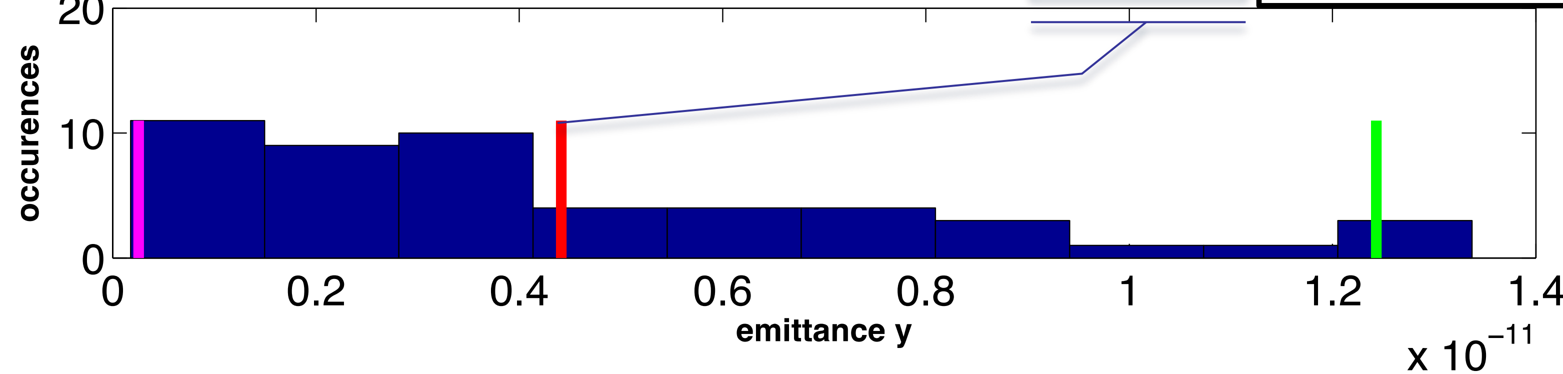
400 μm residual vertical orbit.

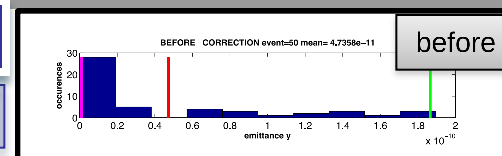
Tested also
Horizontal correction and Skew quadrupoles correction, but still work is in progress.y

First tolerance tests for HER V16

misalignments	ARCS	FF
QUAD SEXT DX,DY	50 μm	30 μm
QUAD SEXT DPHI	100 μrad	50 μrad
Monitor resolution	1 μm	1 μm
Monitors OFFSETs	50 μm	50 μm
DIPOLE DPHI and DTHETA	50 μrad	50 μrad

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



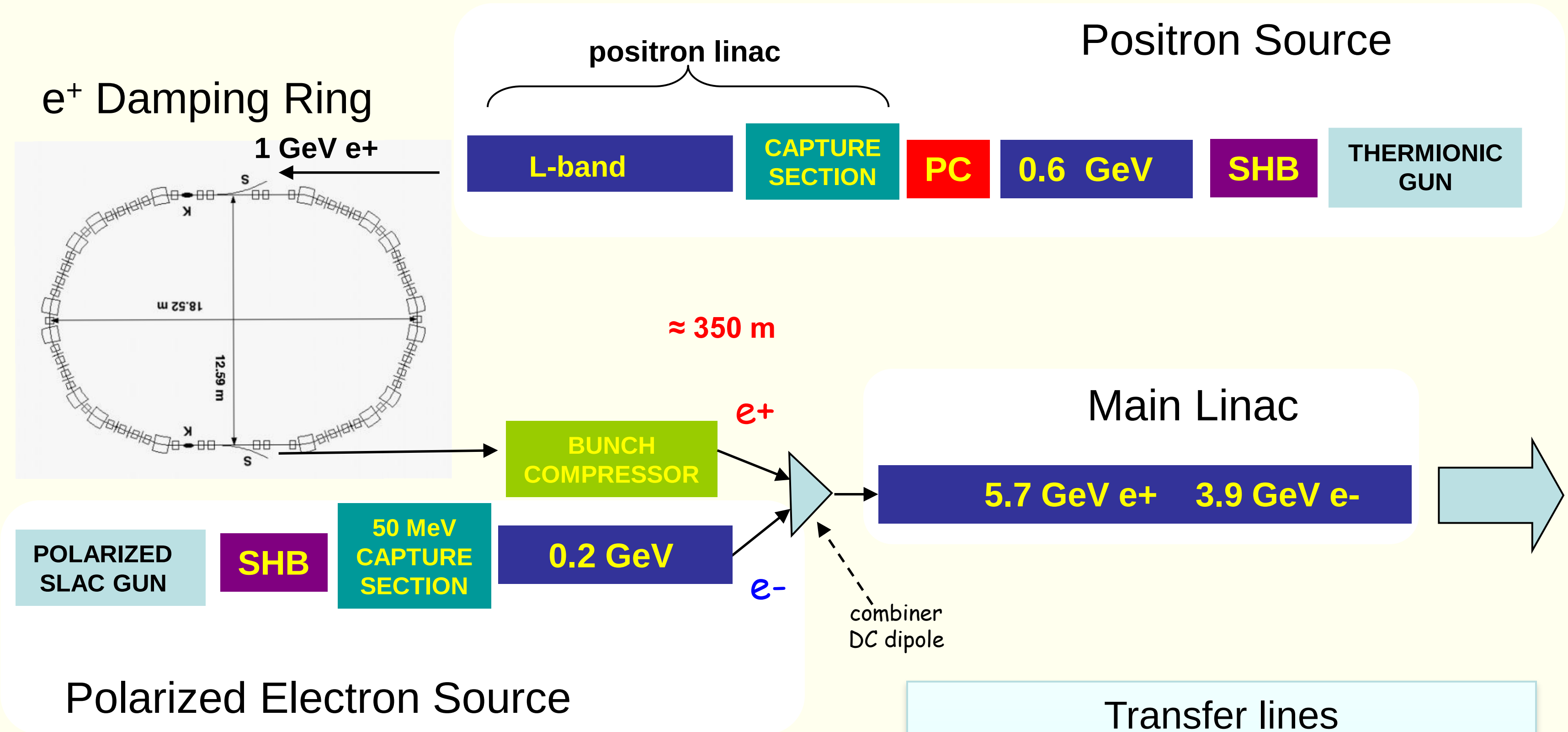


Injection System

Boni, Guiducci, Preger, Variola et al)

- Injection in top-up requires a very stable, reliable injection complex
- At present only e+ beam is stored in Damping Ring (DR) while e- beam is directly accelerated and injected:
  - e+ stored in DR for the time between two injection pulses, achieving same emittance damping factor at twice the repetition frequency
  - with a 100 Hz Linac inject at 50 Hz in each ring using a single bunch per pulse to make the current per bunch very uniform along the bunch trains
- Use SLAC gun (high charge, 10 nC) for the e+ line and have a custom made polarized, low charge, low emittance gun for the e- line
- R&D in progress at LAL/Orsay for the positron source
- R&D at SPARC on C-band Linac maybe useful also (shorter)

Injection system layout



Transfer lines
Positron Source to Damping Ring
Damping Ring to Main Linac
Electron Source to Main Linac
Main Linac to HER
Main Linac to LER

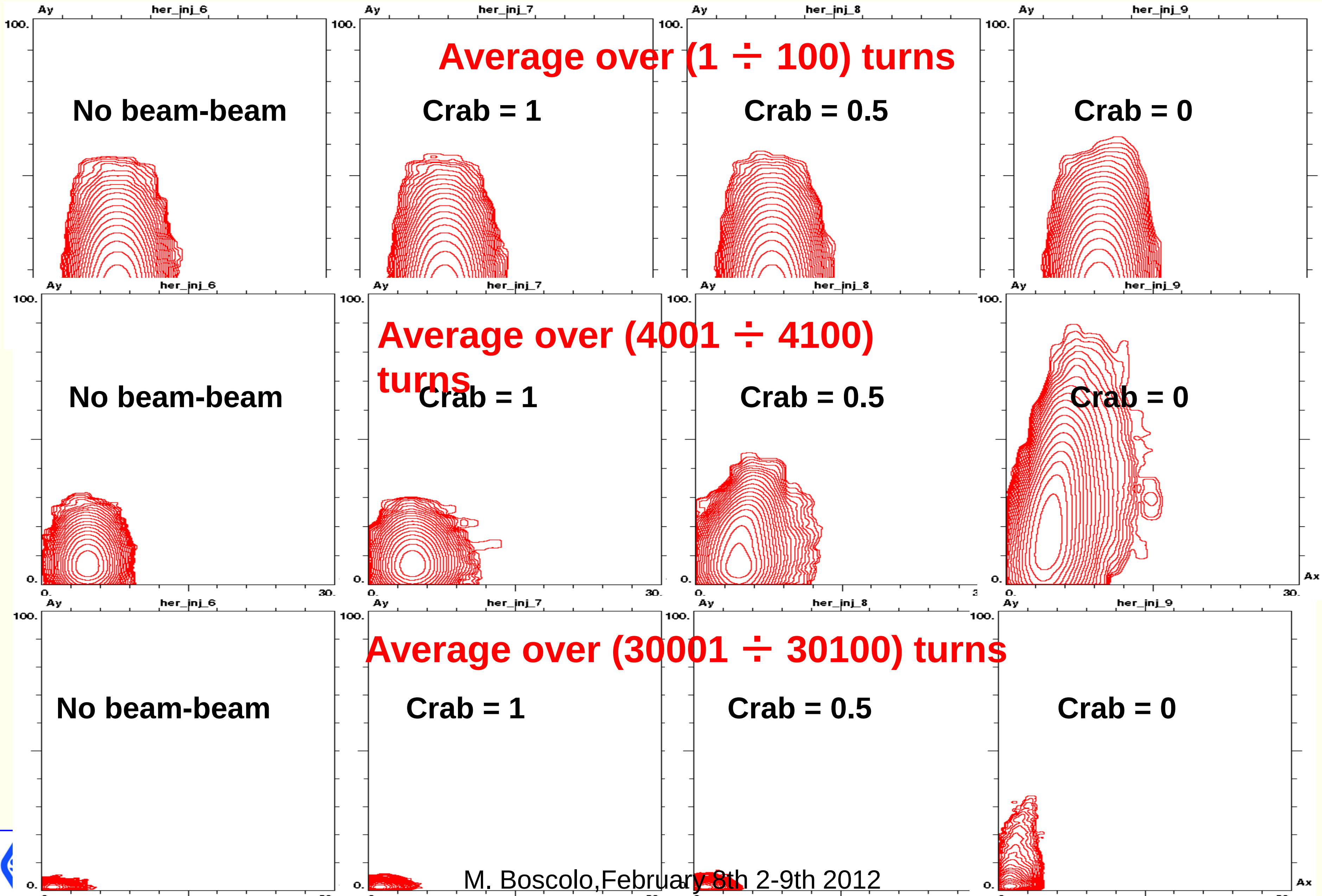
Details:
"SuperB Progress Reports – Accelerator", (Dec. 2010) – Chapter 15
http://arxiv.org/abs/1009.6178v3.
"Updated Design of the Italian SuperB Factory Injection System", IPAC' 11

Injection Complex

- Present status
  - Parameters and site layout selected
  - Layout and parameters of the system components defined
  - Beam dynamics evaluation started
- Remaining work:
  - Baseline decision on electron source: direct injection or DR
  - Baseline decision on positron source: conversion at low energy (.6 GeV), L-band linac for capture and acceleration up to 1 GeV (or a combination of S and L band)
  - Transfer lines layout and composition follows
- Systems ready for TDR
  - Damping ring
  - Main linac

Injection tracking with bb

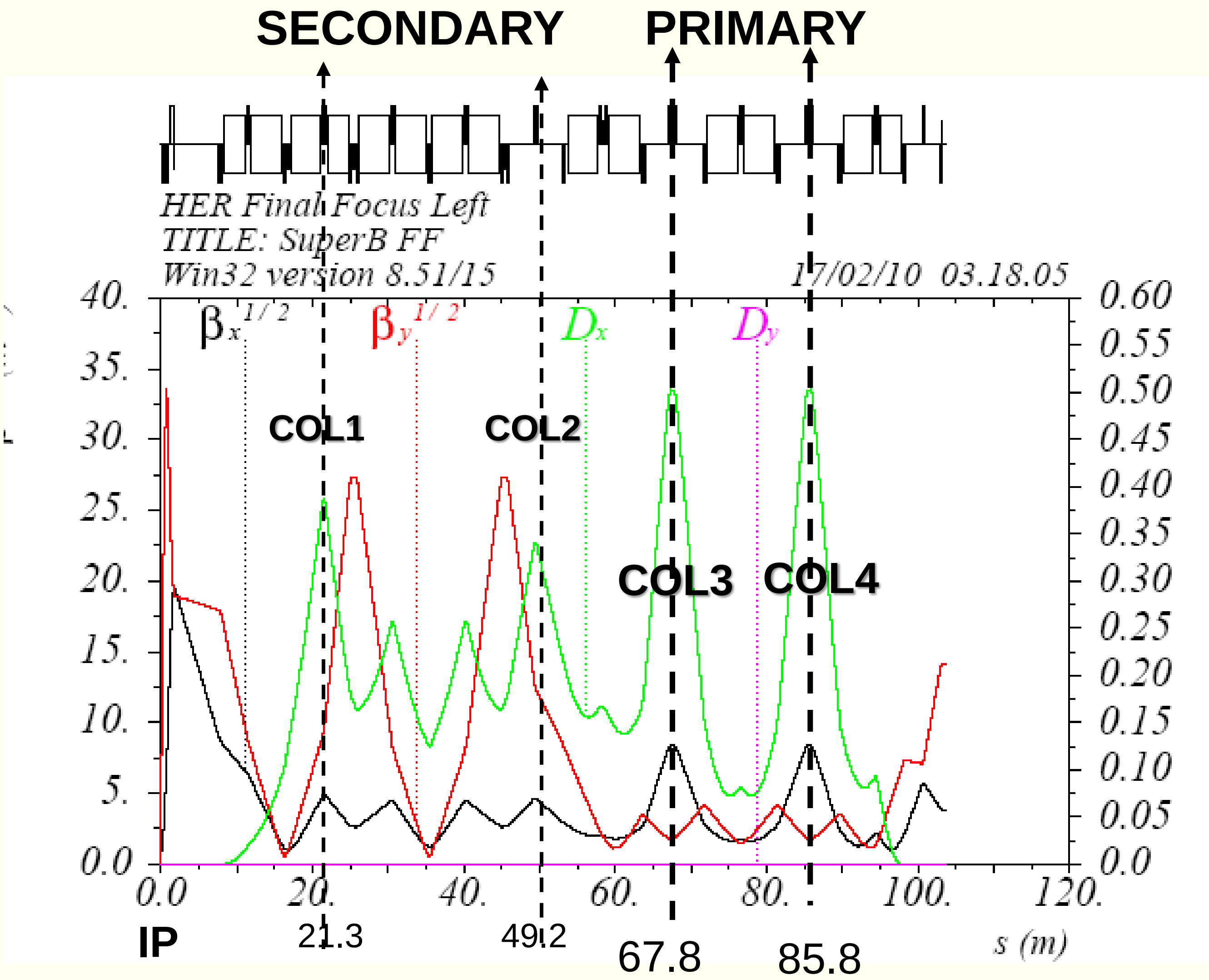
Shatilov



HER / LER Final Focus Horizontal collimators

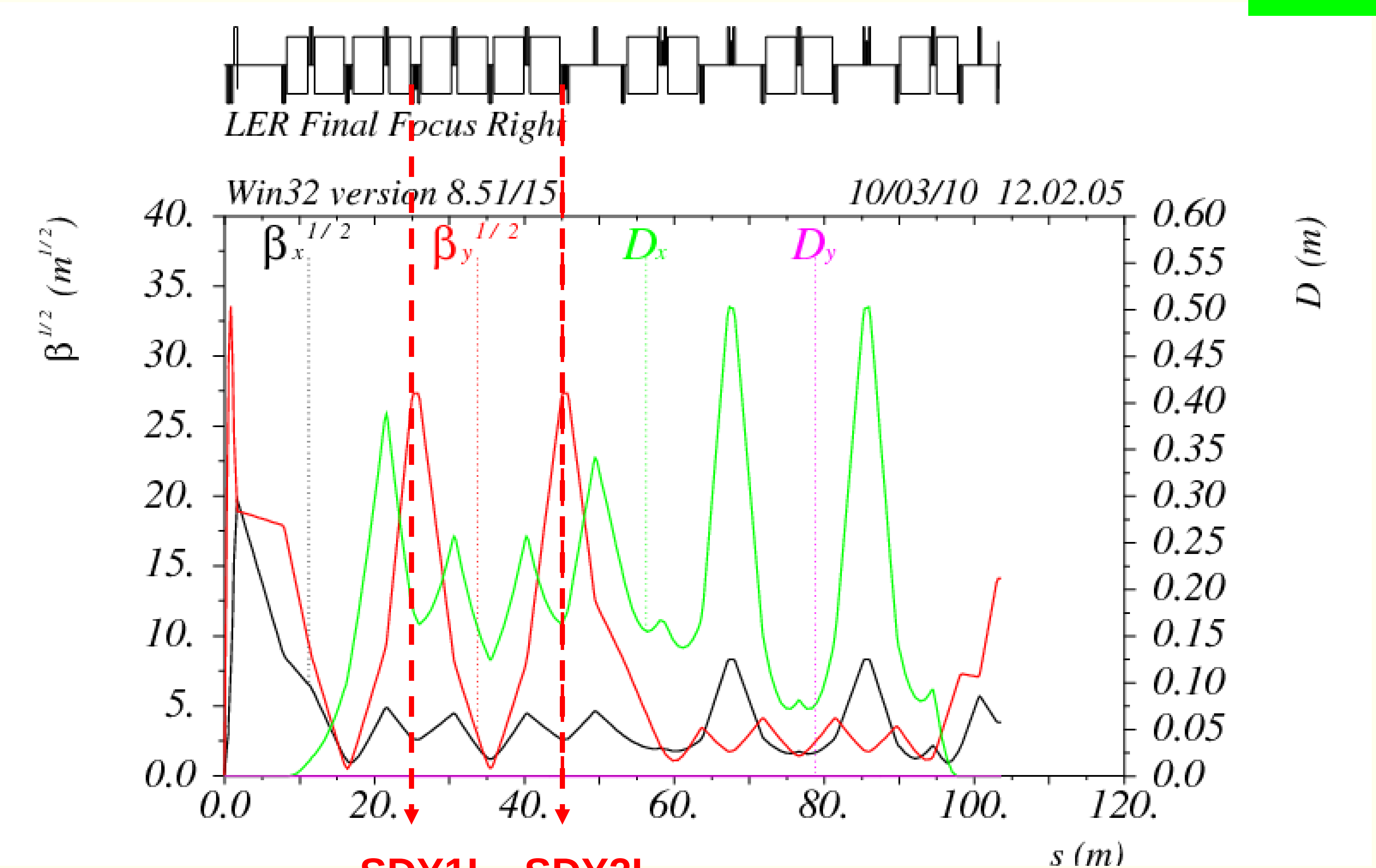
Boscolo

Collimators are located where βx and Dx are large



HER / LER Final Focus Vertical collimators

Boscolo



SDY1L SDY2L

Feedbacks

Drago

- ✓ *Synchrotron bunch-by-bunch feedback* : a strong R&D program has been carried on and the results are test for ver the is n sim letti mo sma of e ope bea

- ✓ *Betatron bunch-by-bunch feedback systems*: same as the previous. A strong R&D program has b g D S b a e st fo te

- ✓ *Tune feedback*: not a big system; it can be tested a b

- ✓ C c c o d

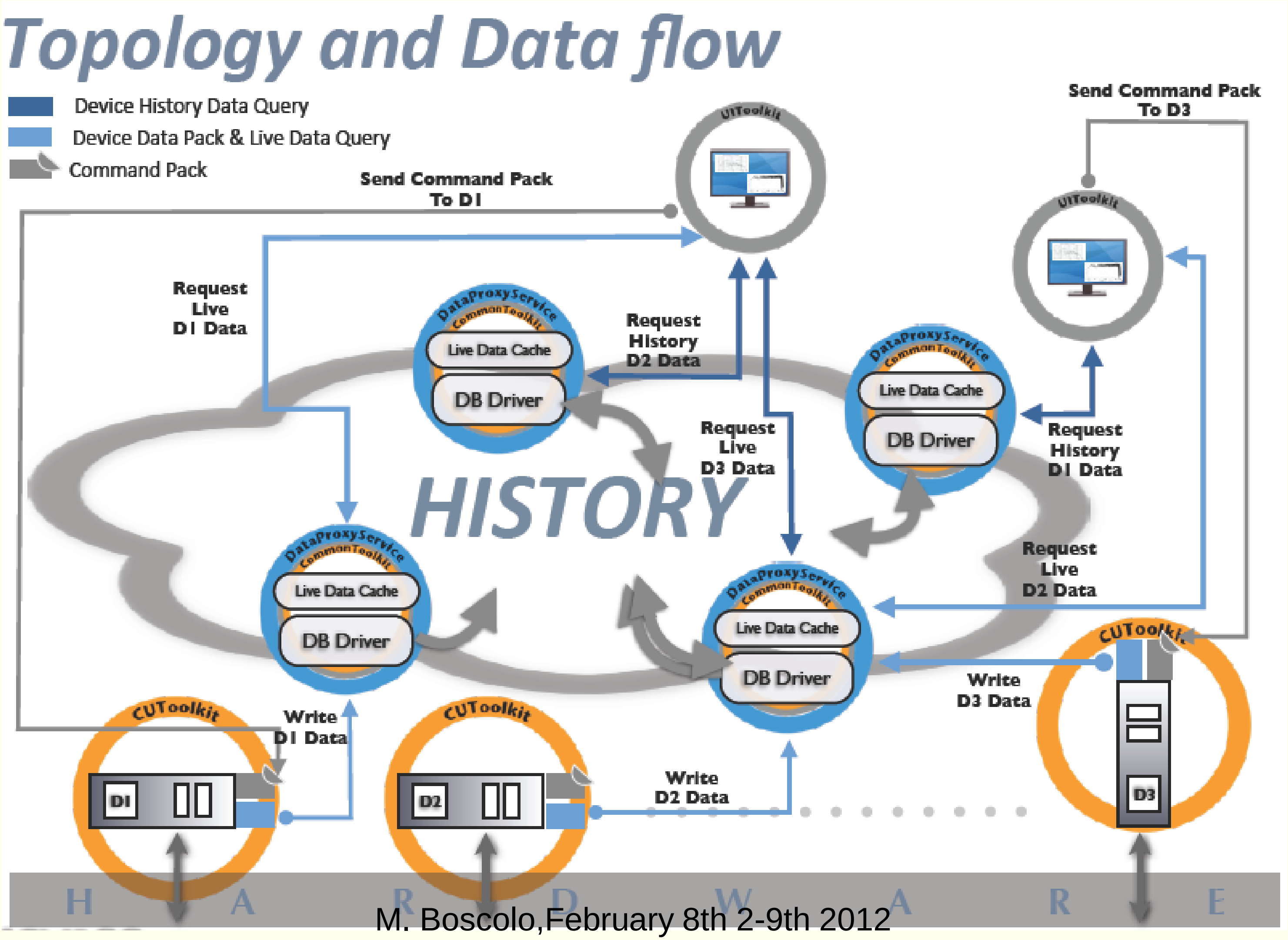
- ✓ II c s

- ✓ *Fast IP feedback*: R&D on this system are very preliminary stage; in my opinion this system will be complementary to the orbit feedback, working in a smaller vertical range. A first analog & digital board, based on Virtex-6 FPGA is in the lab but to carry on serious efforts we need 1 system analyst (myself) + 1 sw engineer + 1 fpga engineer + 1 technician

R&D on Controls (!CHAOS)

Bisegni

- This activity attracted interest from several other INFN structures and Universities



SuperB not just a collider…

Brilliance SuperB vs ESRF (and ESRF upgrade)

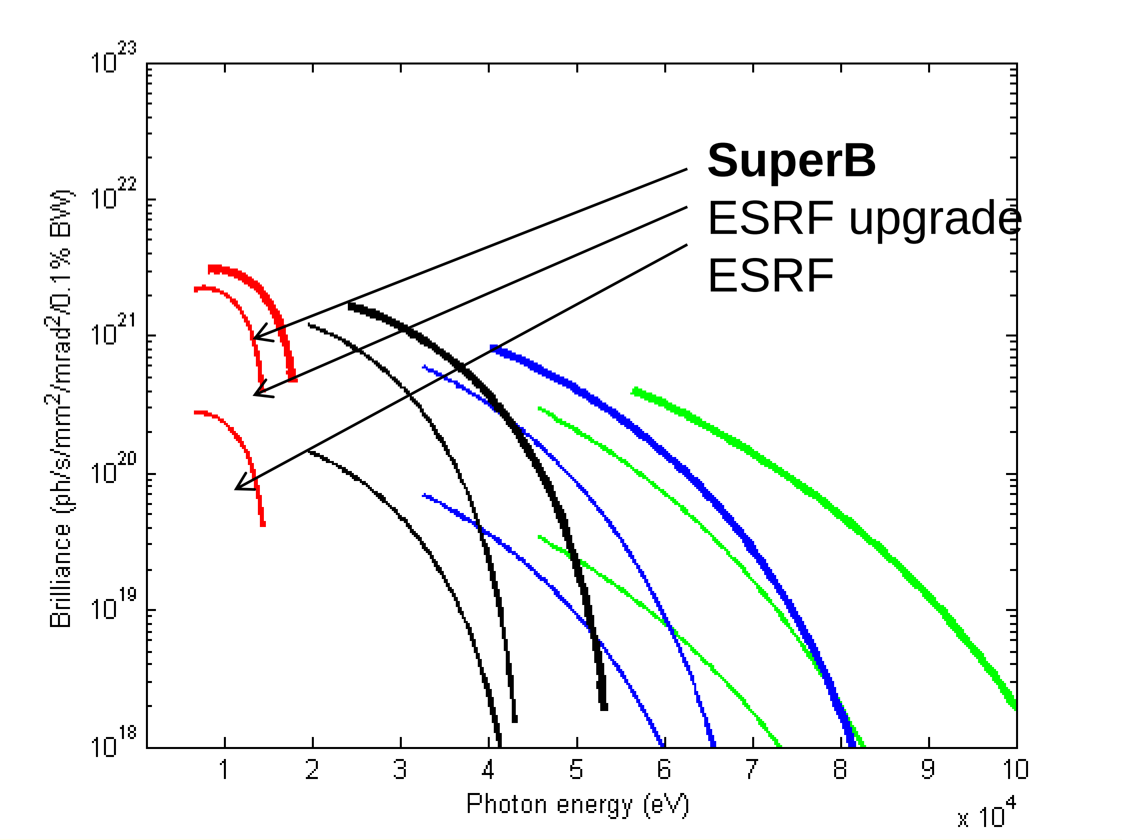
Bartolini

Used U23 of ESRF ID27

ESRF parameters (4nm)
200 mA
0.7% coupling
2 m undulator

ESRF upgrade (4nm)
300 mA
0.3% coupling
4 m undulator

SuperB (2nm)
500 mA
0.7% coupling
2m undulator



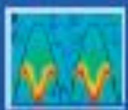
Compatibility with collider operation (current, orbit stability, heat load management,…) needs to be studied

SuperBTF

Quintieri

Preliminary Studies for an extracted beam and neutron facility

Scientific Motivations: A Multi-purpose facility for research with neutrons, proton, pions, muons, ...


Solid State Physics:


Neutron Scattering:

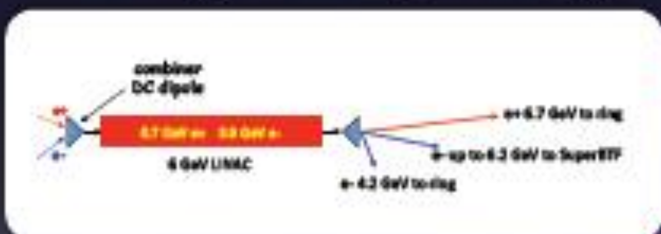

Material Science:


Biology and Biotecnology:


Particle Physics


Detector Calibration

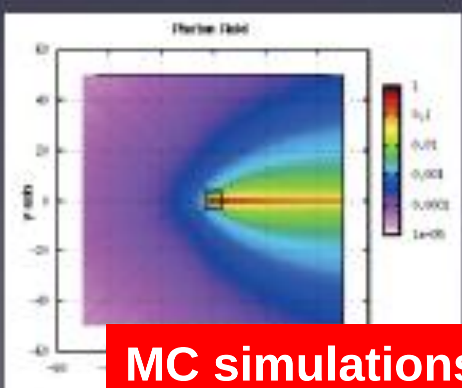
Electrons are sent to impinge on a suitable target and secondary particles are produced by photoproduction

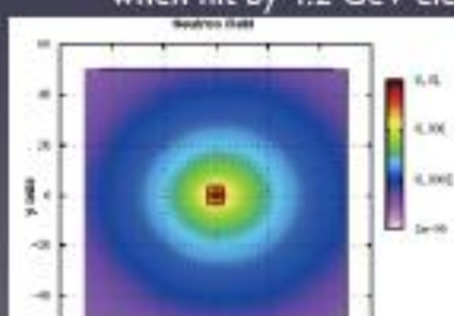


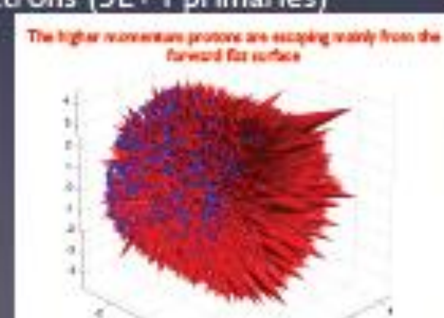
Hadron Yields per primary e- (Ee=4.18 GeV)

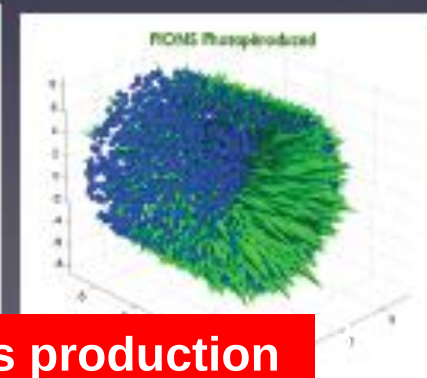
Material	Neutron	Proton	Pion+	Pion-	Muon+	Muon-	Kaon+	Kaon-
W(yaq)	2.51	0.122	7.34E-03	0.012	2.80E-03	2.20E-04	2.73E-05	Negl
U238	3.7	0.06	7.20E-03	[illegible]	2.70E-03	2.40E-04	2.20E-05	Negl
(10ST)-Al	0.162	0.156	5.01E-03	5.29E-02	2.64E-03	1.01E-04	2.92E-06	Negl
(Op)Cu	9.46E-01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Results of MC simulations of photon and neutron field around the target and protons and pions+ escaping from a W target when hit by 4.2 GeV electrons (5E+4 primaries)









MC simulations of different targets for different particles production

Summary on Accelerator work

- Lattice «close» to be frozen, some more work needed on beam dynamics issues
- We do have some systems «close» to TDR phase
- Some strategical design choices still to be taken (ex. in injection system)
- Most important issues to solve in the next months have been identified
- R&D on control system started
- R&D on new bunch-by-bunch feedback very positive (test at DAΦNE)
- Tests on e-cloud suppression electrodes at DAΦNE successful

Organization

- The Cabibbo Laboratory, in charge of building and operating the SuperB Accelerator and Detector, has been created on October 7th 2011 as a Consortium between INFN and University of Tor Vergata

- Systems (almost) ready for technical design:
  - Magnets, vacuum chamber, support structure of the main rings
  - Beam diagnostic and control
  - Power supplies
  - Damping ring
  - Linear accelerator
  - Polarized electron source and positron source

List of present partners

Country	Partner	Location	Short name	Contact person
Italy	Istituto Nazionale Fisica Nucleare	Frascati	INFN-LNF	**M. Biagini**
		Tor Vergata	INFN-ROMA2	**L. Catani**
		Pisa + Genova + Napoli	INFN-PI, GE, NA	**E. Paoloni**
		Padova	INFN-PD	**M. Bellato**
		Bari	INFN-BA	**G. Iaselli**
Italy	Italian Institute of Technology	Genova	IIT	**E. Di Fabrizio**
USA	DOE – Stanford Linear Accelerator	Stanford	SLAC	**J. Seeman**
France	Centre National de la Recherche Scientifique	Orsay	IN2P3-LAL	**A. Variola**
		Grenoble	IN2P3-LPSC	**M. Baylac**
		Annecy	IN2P3-LAPP	**A. Jeremie**
UK	John Adams Institute	Oxford	JAI	**A. Seryi**
	DIAMOND	Rutherford	DIAMOND	**R. Bartolini**
Russia	Budker Institute	Novosibirsk	BINP	**E. Levichev**
Poland	**Institute of Nuclear Physics PAS**	**Crakow**	**PAS**	**T. Lesiak**

Conclusions I

- Organization of the accelerator structure is progressing
- We have a draft organization of the accelerator work
- We plan to commission to other laboratories/Institutions parts of the accelerator, taking into account their expertise in the field
- Some examples at present:
  - France for the positron source, FF vibration control, ground measurements,…
  - England for the Final Focus, IP feedback, SL beamlines,…
  - BINP for DR, special magnets, vacuum pipe,…
  - SLAC for PEP-II components (RF, magnets,…)
  - Poland for installation and tests (tbd)

Conclusions II

- An MOU with SLAC for procurement of PEP-II equipment is being prepared
- Synchrotron Light Italian community started to consider SuperB properties for SL users → needs more thoughts on maximum current, operation mode, experiments (will probably require a dedicated session at next Collaboration Meeting)
- MC simulations on the possibility to have a «SuperBeamTestFacility» started → interest from users
- An update of costs estimate will be prepared for this summer
- With the Cabibbo Laboratory now in place we will be ready very soon to hire personnel and reinforce the collaboration in order to finish TDR and start digging the tunnel
- ***Next Collaboration Meeting at LNF March 19-23***