Summary Accelerator

U. Wienands

SLAC-ASD

CDR, May 2007

- Established overall architecture, crab waist IR
- Overall set of machine parameters
- Lattices, based on ILC DR designs
- significant amount of beam-beam simulations
- Identification of major collective and intensity effects
- Identification of potentially suitable PEP-II components
- Tor Vergata site

Progress since CDR

- Crab Waist test results
- Optimized machine parameters
  - refined lattice, optimized for performance, smaller
  - reduced rf power requirements
- Refinement of IR design
  - defining magnet requirements, apertures & space, trajectories
  - dual-aperture QD0
- Beginning investigation of spin handling
- Refinement of injector requirements and design
- Initial look at feedback requirements & possible architecture

Progress Breakdown

Facility

Crab Waist

Accelerators

IR

Polarization

Intensity

Feedbacks

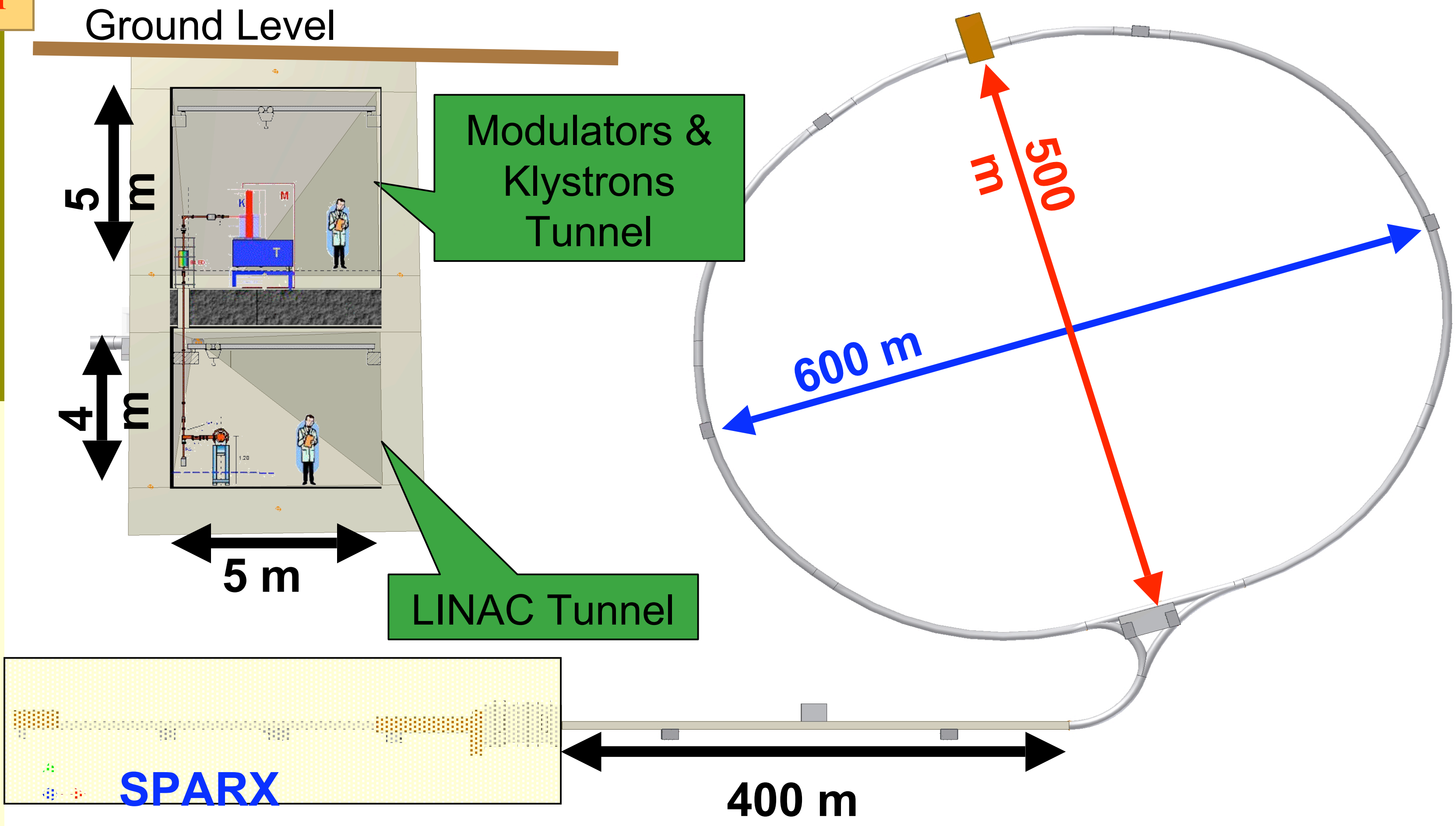
Injector

Wrap-Up

SuperB: Tunnel

A. Tomassini

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up



Crab Waist IR

P. Raimondi

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

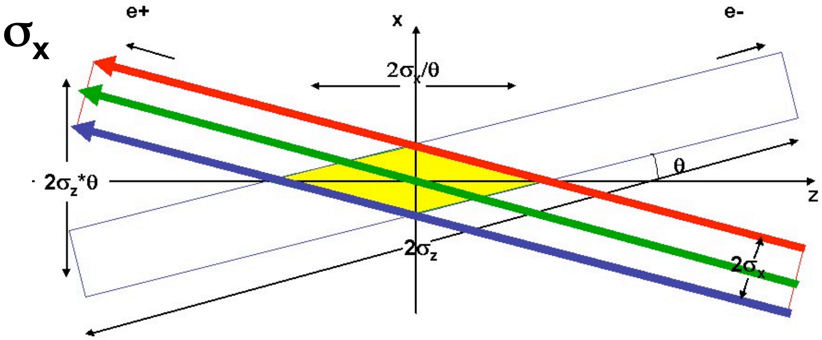
Large Piwinski angle $\Phi_{P}=\theta\sigma_z/\sigma_x$

Geometric luminosity gain

Very low horizontal tune shift

No parasitic collisions

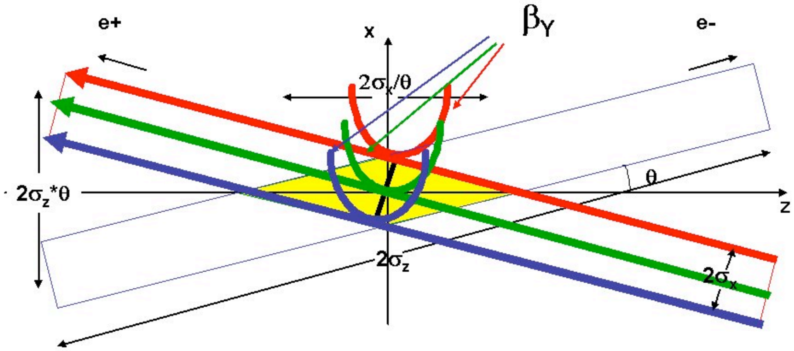
short overlap region



small β_y^* ($\beta_y^* \sim \sigma_x/\theta$)

Geometric luminosity gain

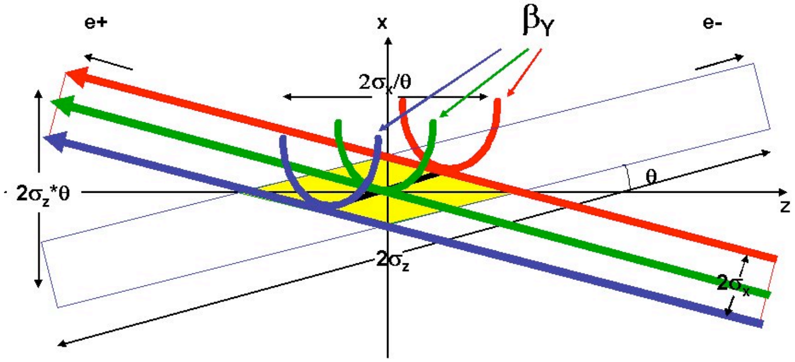
low vertical tune shift



Crab waist transformation (realized with two sextupoles @π in x and 1.5π in y from IP)

Geometric luminosity gain

Suppression of X-Y betatron and synchrobetatron resonances



CRAB SEXTUPOLES WORK !!

P. Raimondi

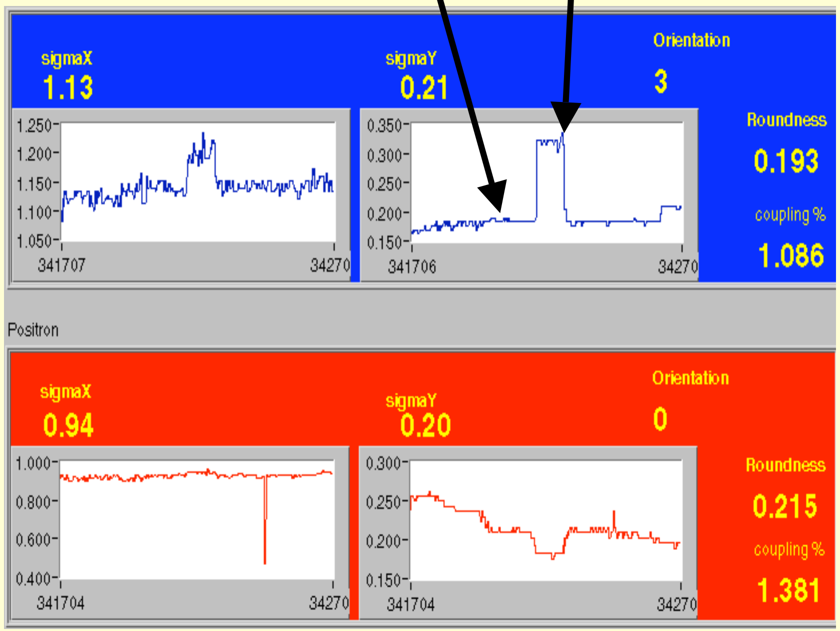
- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up

LUMINOMETERS

e^- sextupoles on

Transverse beam sizes at Synchrotron Light Monitors

e^- sextupoles off



sigmaX 1.13

sigmaY 0.21

Orientation 3

Roundness 0.193

coupling % 1.086

Positron

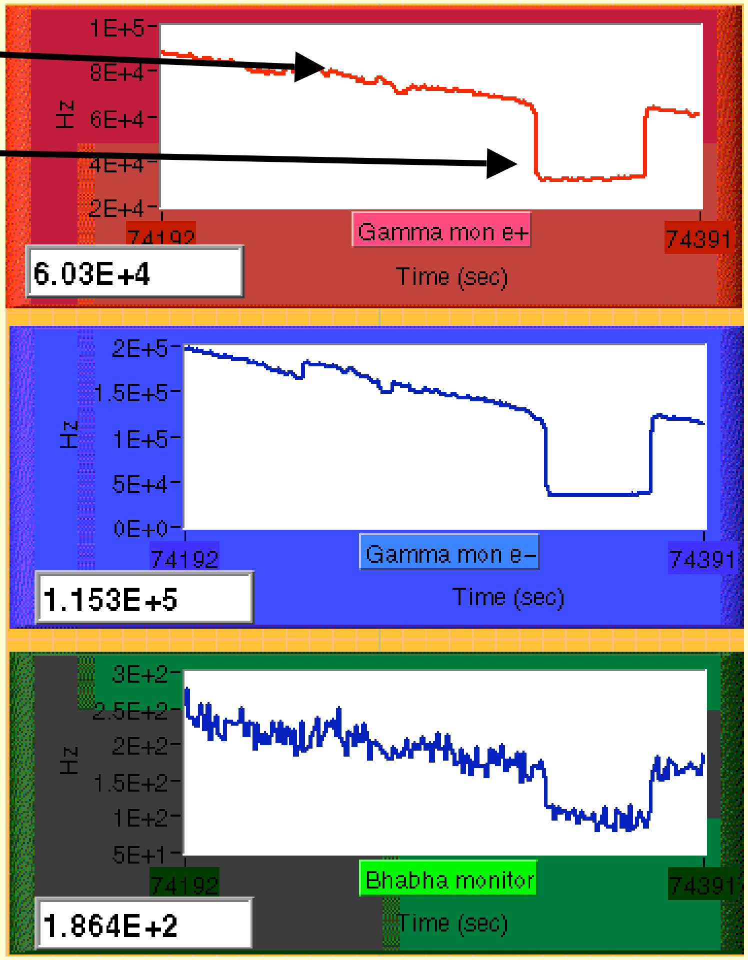
sigmaX 0.94

sigmaY 0.20

Orientation 0

Roundness 0.215

coupling % 1.381



Gamma mon e+ 6.03E+4

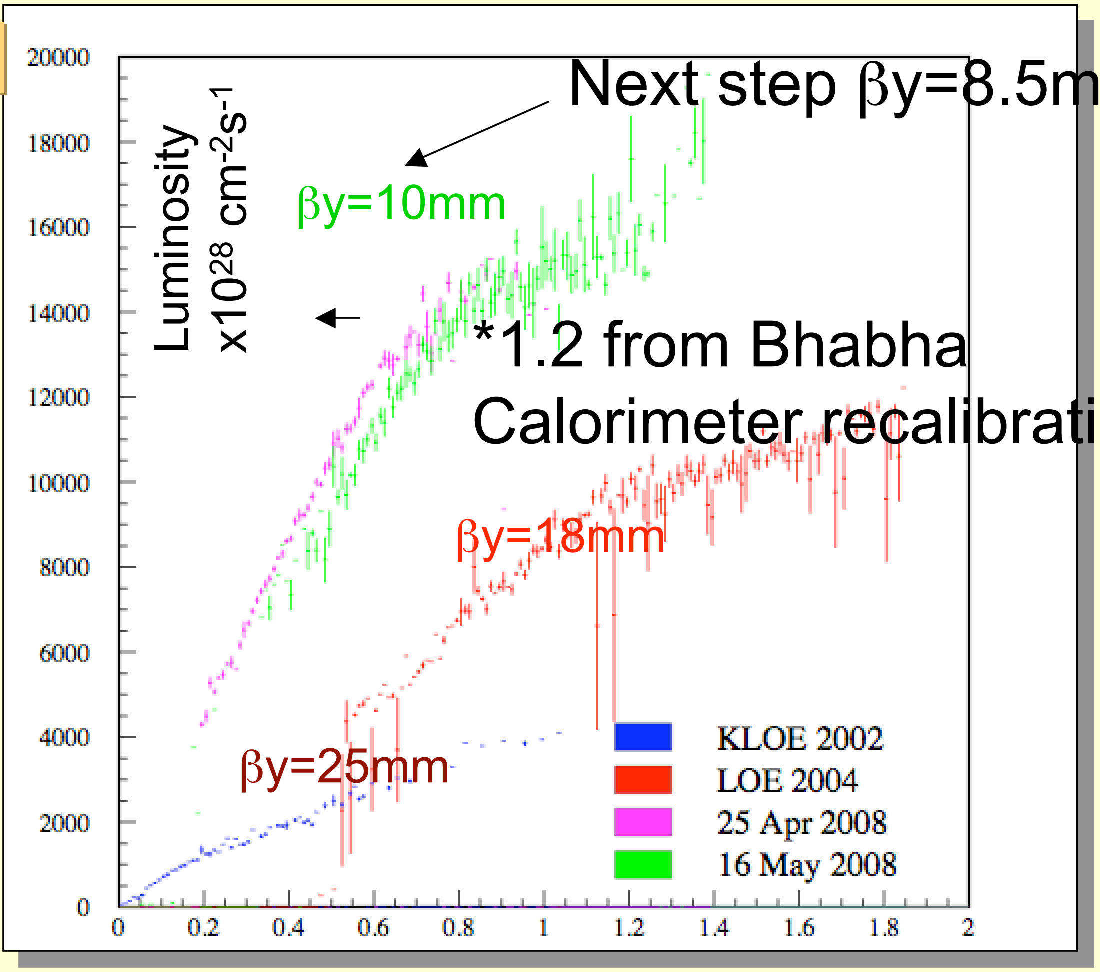
Gamma mon e− 1.153E+5

Bhabha monitor 1.864E+2

Lum vs Beam Currents

P. Raimondi

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up



Next step βy=8.5mm (design 6mm)

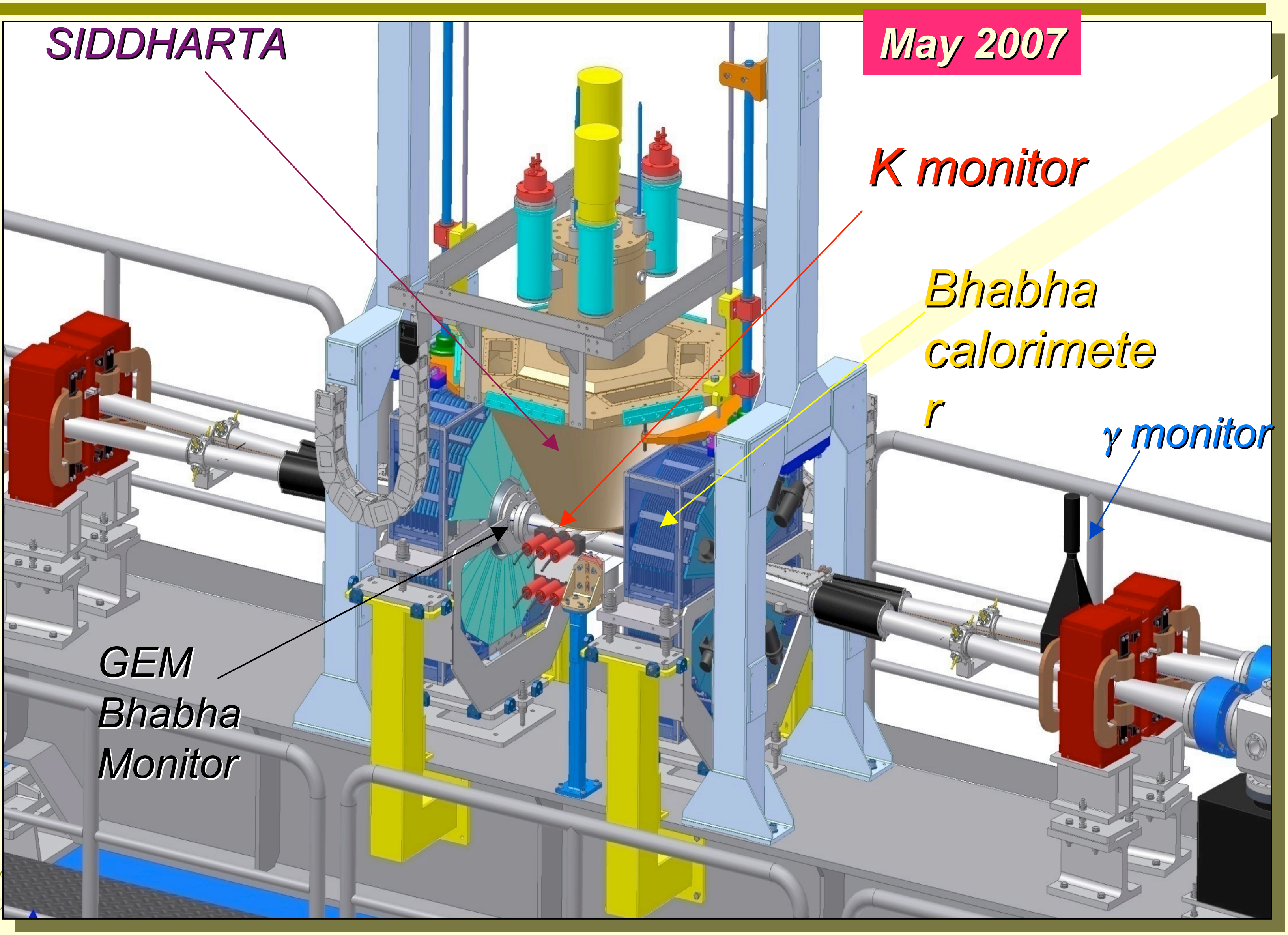
*1.2 from Bhabha Calorimeter recalibration

Higher luminosity versus current as expected

Layout and Luminosity Monitors

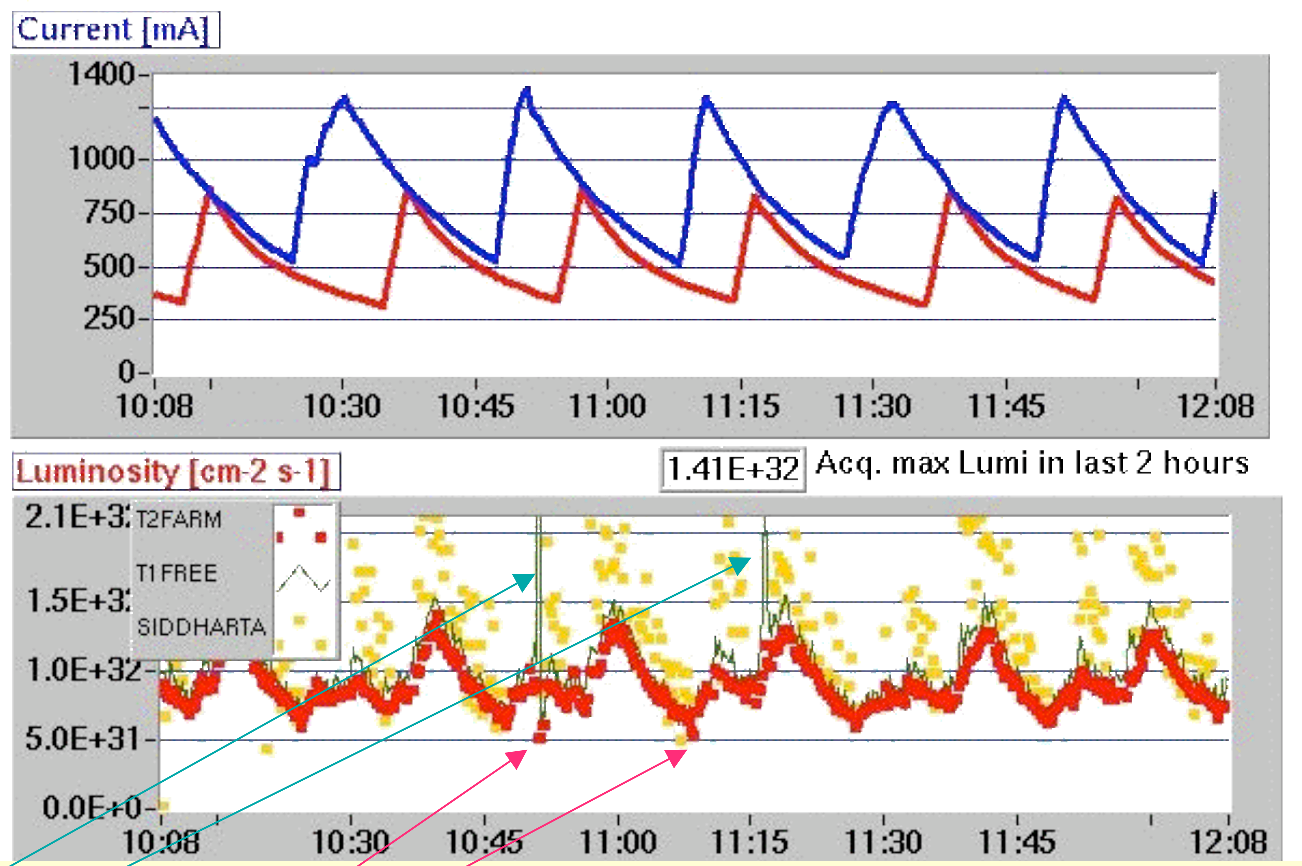
P. Valente

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up



Online filter

P. Valente



During injections T1FREE is jumping up…

… while T2FARM can go down due to injection veto in DAQ

Since April 21st, 2008

Super*B* New Parameters

M. Biagini

	Nominal		Upgrade		Ultimate	
PARAMETER	LER (e+)	HER (e-)	LER (e+)	HER (e-)	LER (e+)	HER (e-)
Energy (GeV)	4	7	4	7	4	7
Luminosity x 10^{36}	1.0		2.0		4.0	
Circumference (m)	1800	1800				
Revolution frequency (MHz)	0.167					
Eff. long. polarization (%)	0	80				
RF frequency (MHz)	476					
Momentum spread ($x10^{-4}$)	7.9	5.6	9.0	8.0		
Momentum compaction ($x10^{-4}$)	3.2	3.8	3.2	3.8		
Rf Voltage (MV)	5	8.3	8	11.8	17.5	27
Energy loss/turn (MeV)	1.16	1.94	1.78	2.81		
Number of bunches	1251				2502	
Particles per bunch ($x10^{10}$)	5.52				6.78	
Beam current (A)	1.85				3.69	
Beta y* (mm)	0.22	0.39	0.16	0.27		
Beta x* (mm)	35	20				
Emit y (pm-rad)	7	4	3.5	2		
Emit x (nm-rad)	2.8	1.6	1.4	0.8		
Sigma y* (microns)	0.039	0.039	0.0233	0.0233		
Sigma x* (microns)	9.9	5.66	7	4		
Bunch length (mm)	5		4.3			
Full Crossing angle (mrad)	48					
Wigglers (#) 20 meters each	0	0	2	2		
Damping time (trans/long)(ms)	40/20	40/20	28/14	28/14		
Luminosity lifetime (min)	6.7		3.35			
Touschek lifetime (min)	20	40	38	20		
Effective beam lifetime (min)	5.0	5.7	3.1	2.9		
Injection rate pps ($x10^{11}$) (100%)	2.6	2.3	5.1	4.6	10	9.1
Tune shift y (from formula)	0.15		0.20			
Tune shift x (from formula)	0.0043	0.0025	0.0059	0.0034		
RF Power (MW)	17		25		58.2	

Beam-beam transparency conditions in red

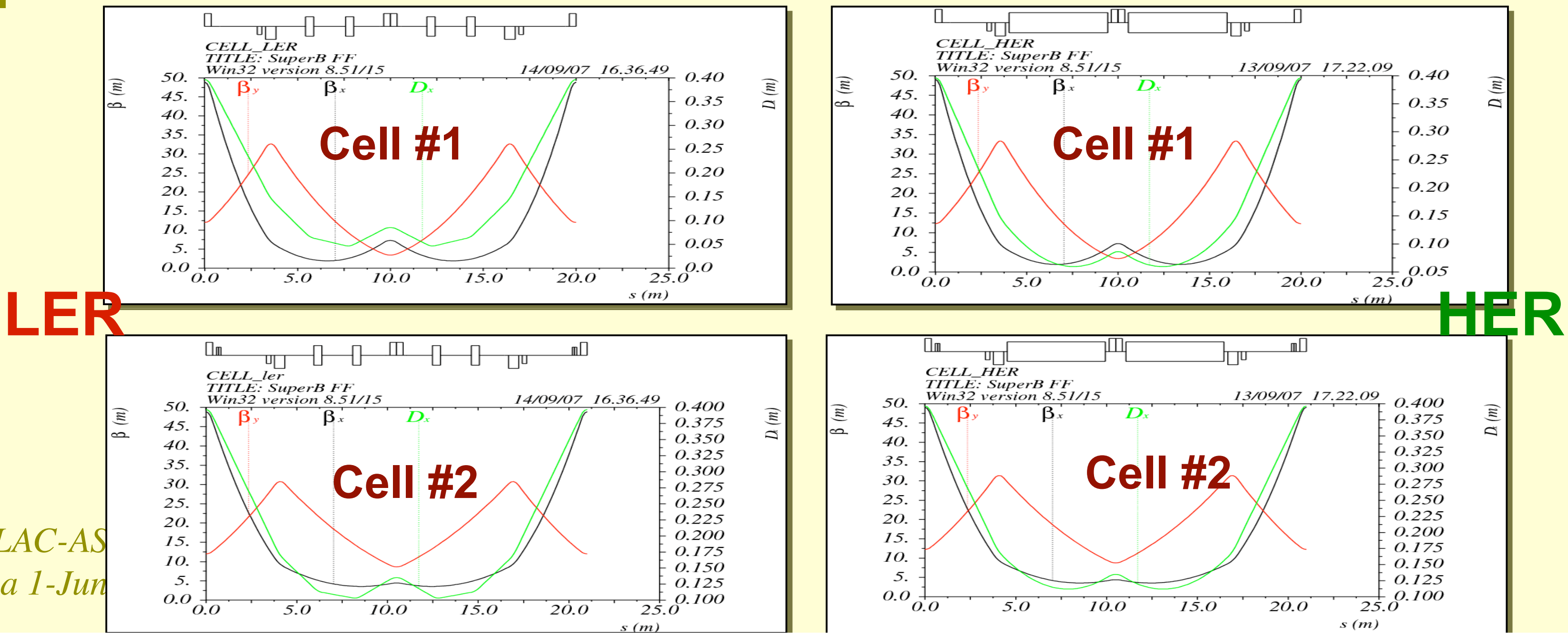
- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up

New Lattice

M. Biagini

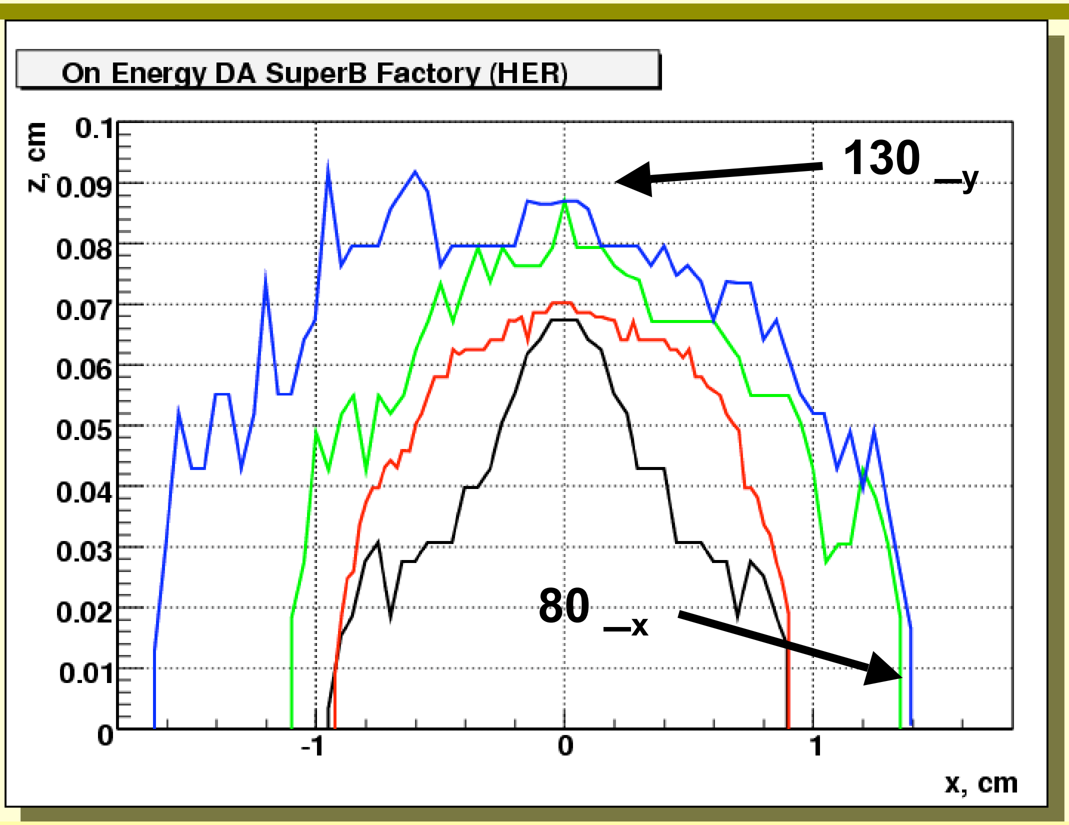
Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

- Alternating sequence of two different arc cells:
  - $\mu_x = \pi$ cell, that provides the best dynamic aperture,
  - $\mu_x = 0.72*2\pi$ cell with much smaller intrinsic emittance, which provides phase slippage for sextupoles pairs, so that one arc corrects all phases of chromaticity.
  - chromatic function $W_x < 20$ everywhere
  - β and α variation with particle momentum are close to zero
  - larger dynamic aperture



New Lattice Acceptance

M. Biagini



Black: original DA at WP (.575/.595)

Red: optimized at WP (.575/.595)

Green: DA for the new WP (.569/.638), same sextupoles

Blue: DA re-optimized in the new WP (.569/.638)

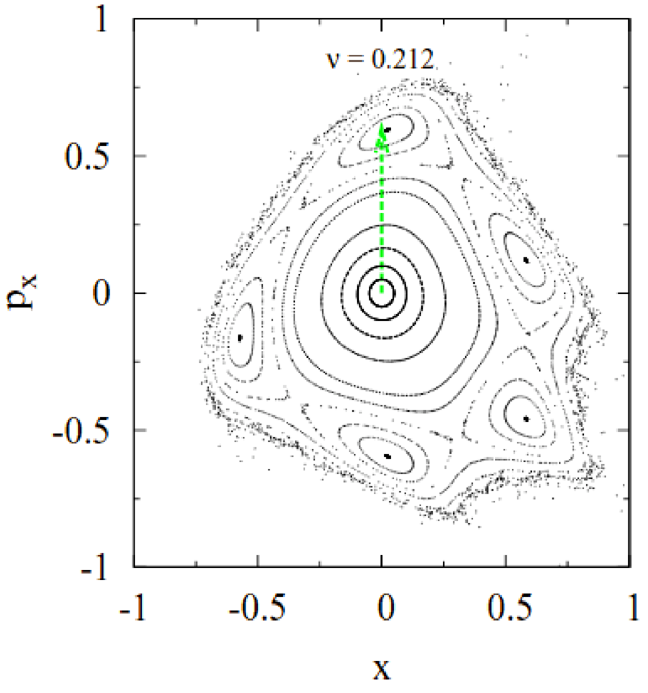
P.Piminov, BINP

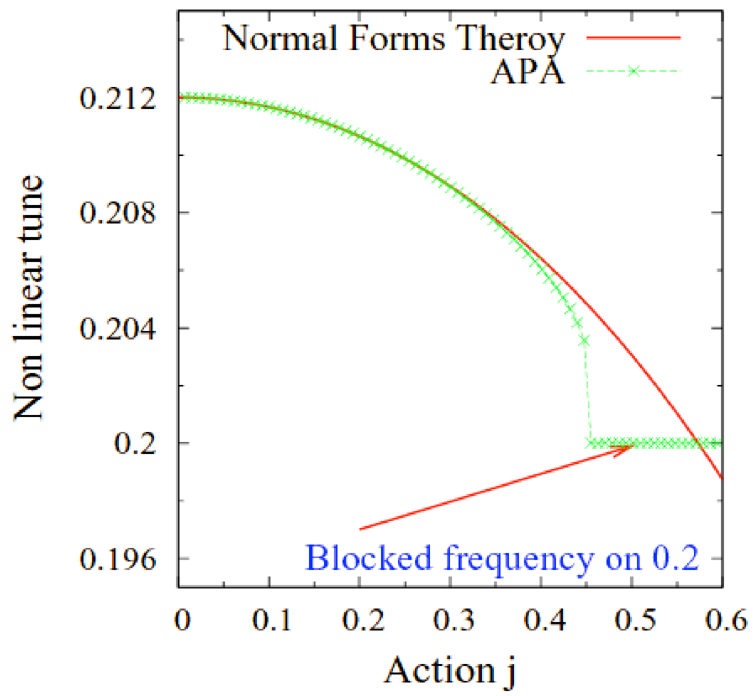
Lattice Acceptance/Tracking

D. Quatraro

- Can use Normal-Form Analysis to analyse lattice:

$$\begin{pmatrix}\hat{x}'\\ \hat{p}_x'\\ \hat{y}'\\ \hat{p}_y'\end{pmatrix} = \mathbf{R}(\omega)\begin{pmatrix}\hat{x}\\ \hat{p}_x + \frac{K_2}{2}\beta_x^{3/2}(\hat{x}^2-\beta\hat{y}^2)\\ \hat{y}\\ \hat{p}_y - K_2\beta_x^{3/2}\beta\hat{x}\hat{y}\end{pmatrix} \Rightarrow \begin{cases}\omega = (\omega_x,\omega_y) \text{ linear tunes}\\ \mathbf{R} = \text{rotation matrix}\\ \beta = \beta_y/\beta_x\end{cases}$$





New IR Design

M. Sullivan

- QD0 has two centers – one for each beam (septum QD0)
  - Bore has to be cold – no room for warm bore
  - Means very low SR power on the walls
  - Minimal bending of incoming and outgoing beams
  - QDO centers are parallel to detector axis

Facility

Crab Waist

Accelerators

IR

Polarization

Intensity

Feedbacks

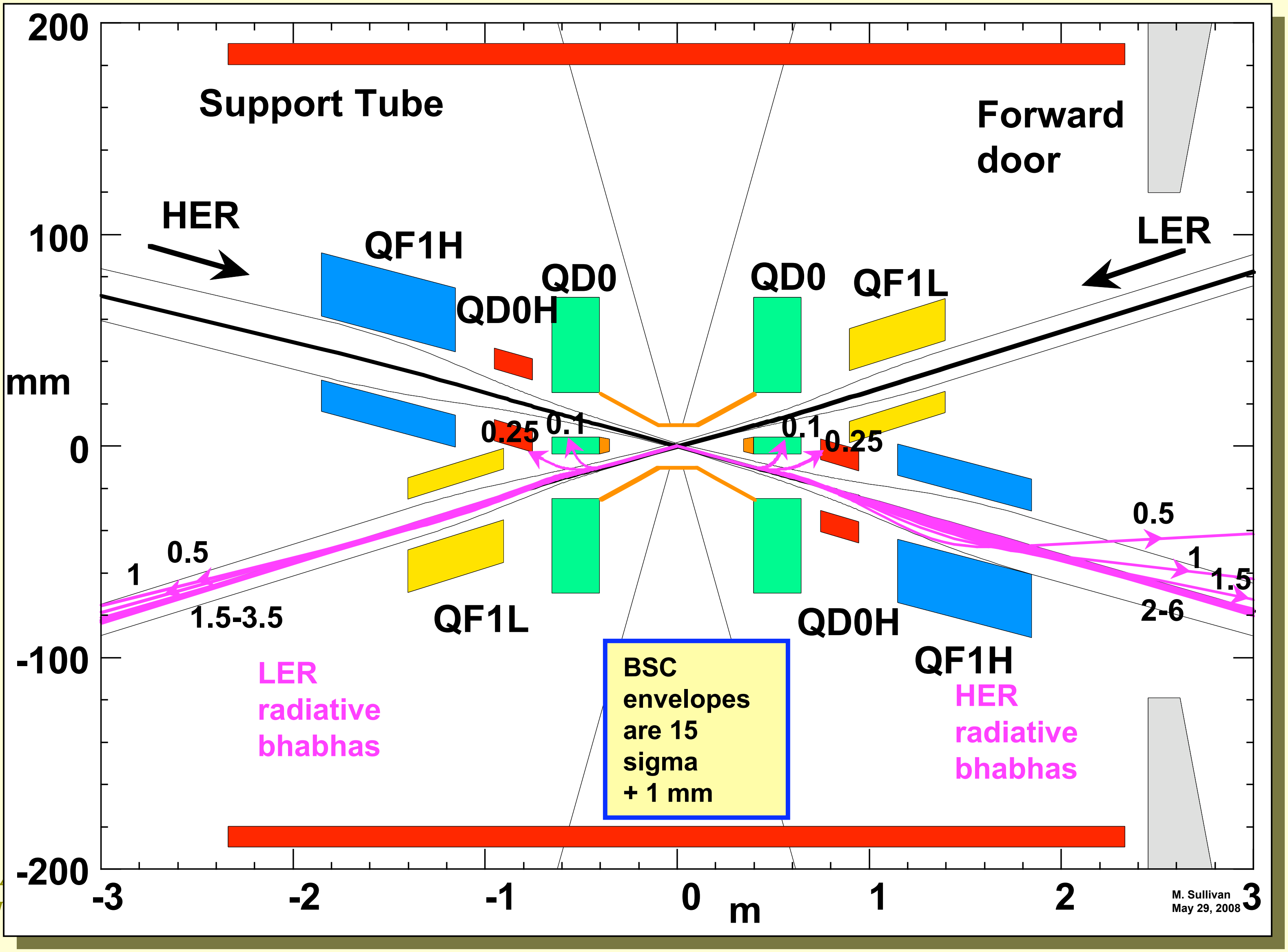
Injector

Wrap-Up

New IR design with BaBar

M.
Sullivan

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up



BSC envelopes are 15 sigma + 1 mm

Option 2: twin Siamese quads

S. Bettoni/
E. Paoloni

Facility

Crab Waist

Accelerators

IR

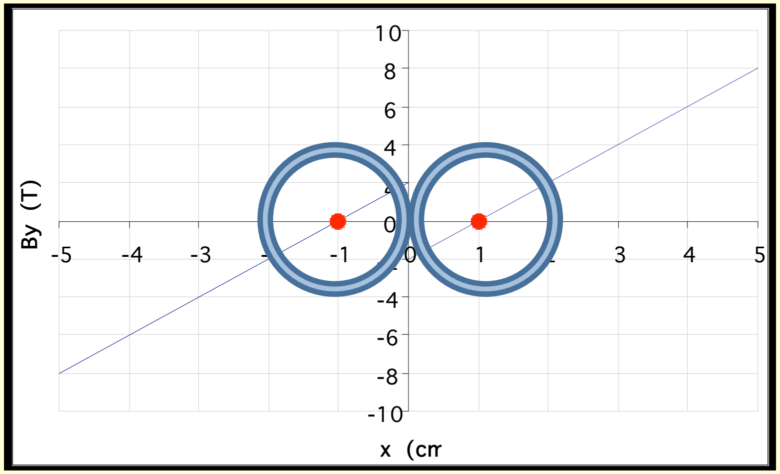
Polarization

Intensity

Feedbacks

Injector

Wrap-Up



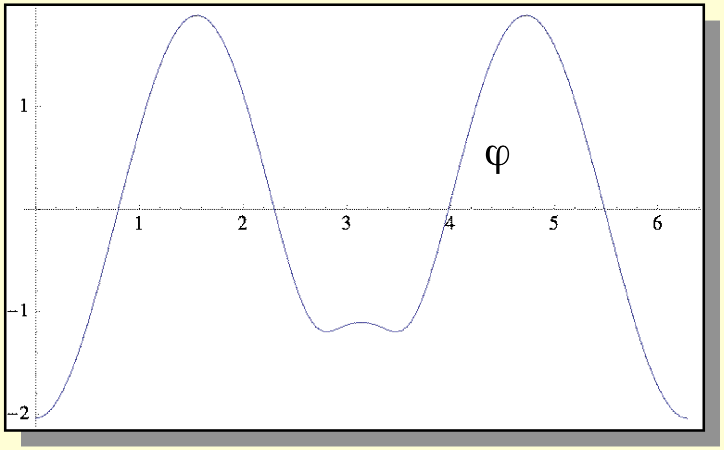
- Beams very closed @ QD0 entrance (2 cm)
- 60 _ (_$_x$ ~ 110 _m) beam envelope leaves space for a very thin double quadrupole (3-4 mm allowable space)
- Cross talk among the two magnets not negligible

Novel QD0 design based on SC *helical-type* windings

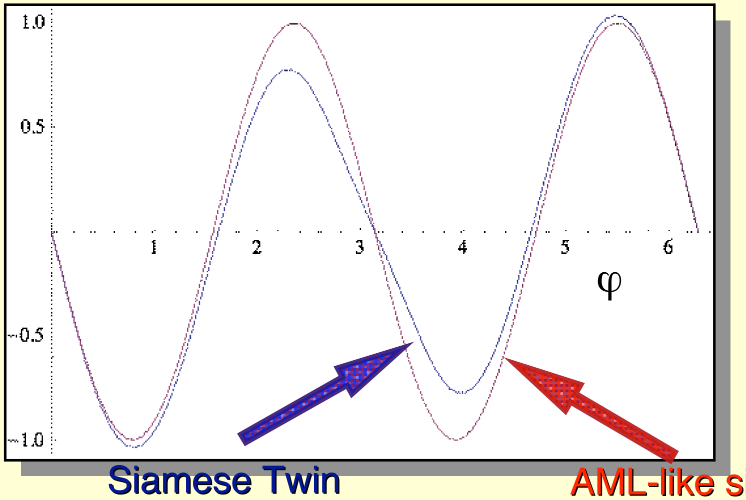
The winding shape

S. Bettoni/
E. Paoloni

Starting from the principle of the AML *ideal* multipolar magnet optimize the winding shape to produce an ideal quadrupolar field centered on each of the beams

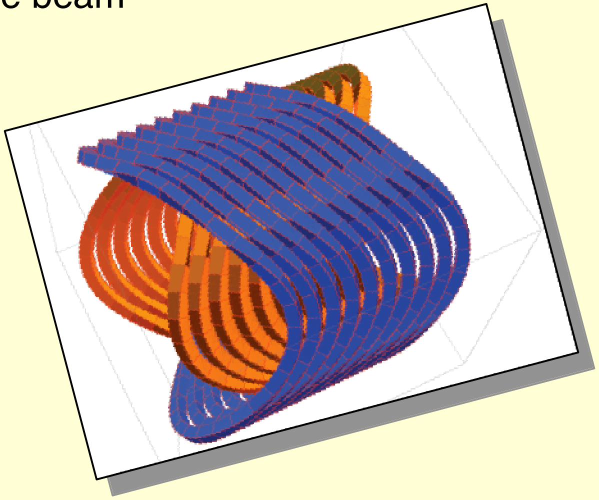


Two counter rotating windings to cancel out the inner solenoidal field and the outer field generated by the magnet centered on the close beam



Siamese Twin Quadrupole

AML-like single Perfect Quadrupole



IR with Solenoid Rotator

Wienands/
W. Wittmer

Facility

Crab Waist

Accelerators

IR

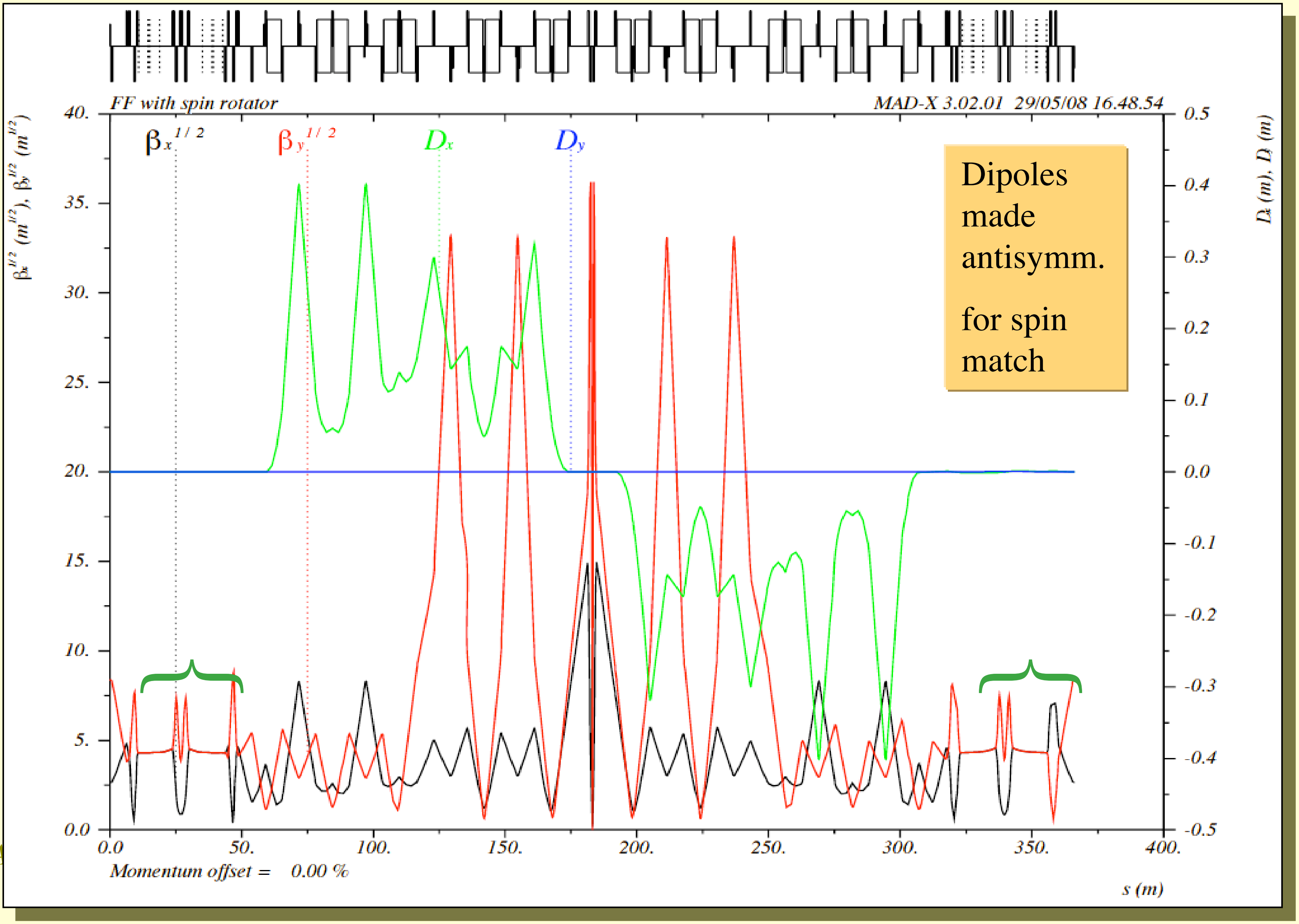
Polarization

Intensity

Feedbacks

Injector

Wrap-Up



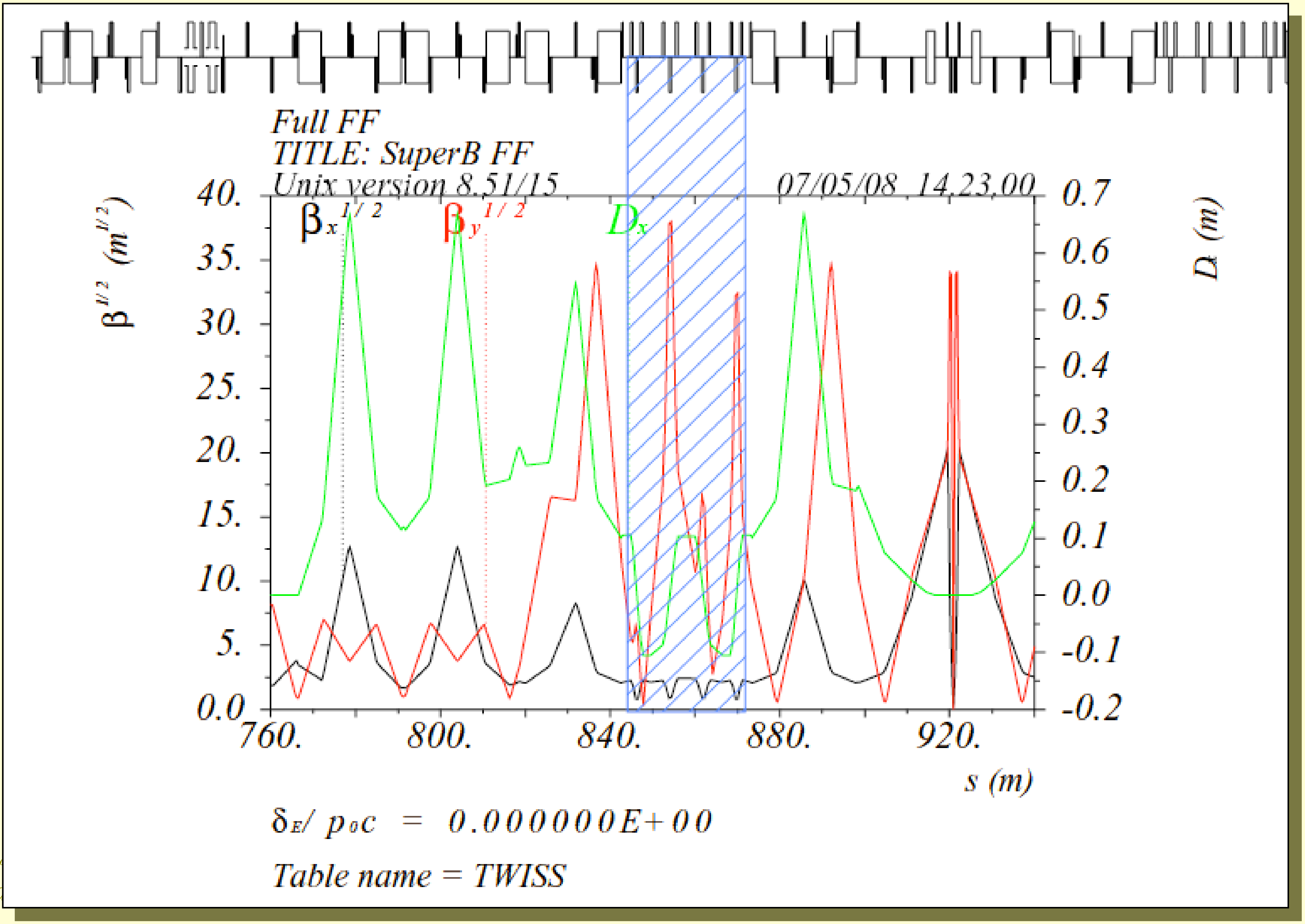
Dipoles made antisymm.

for spin match

Spin Rotator in IR Lattice

Bogomyagkov
Nikitin

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up

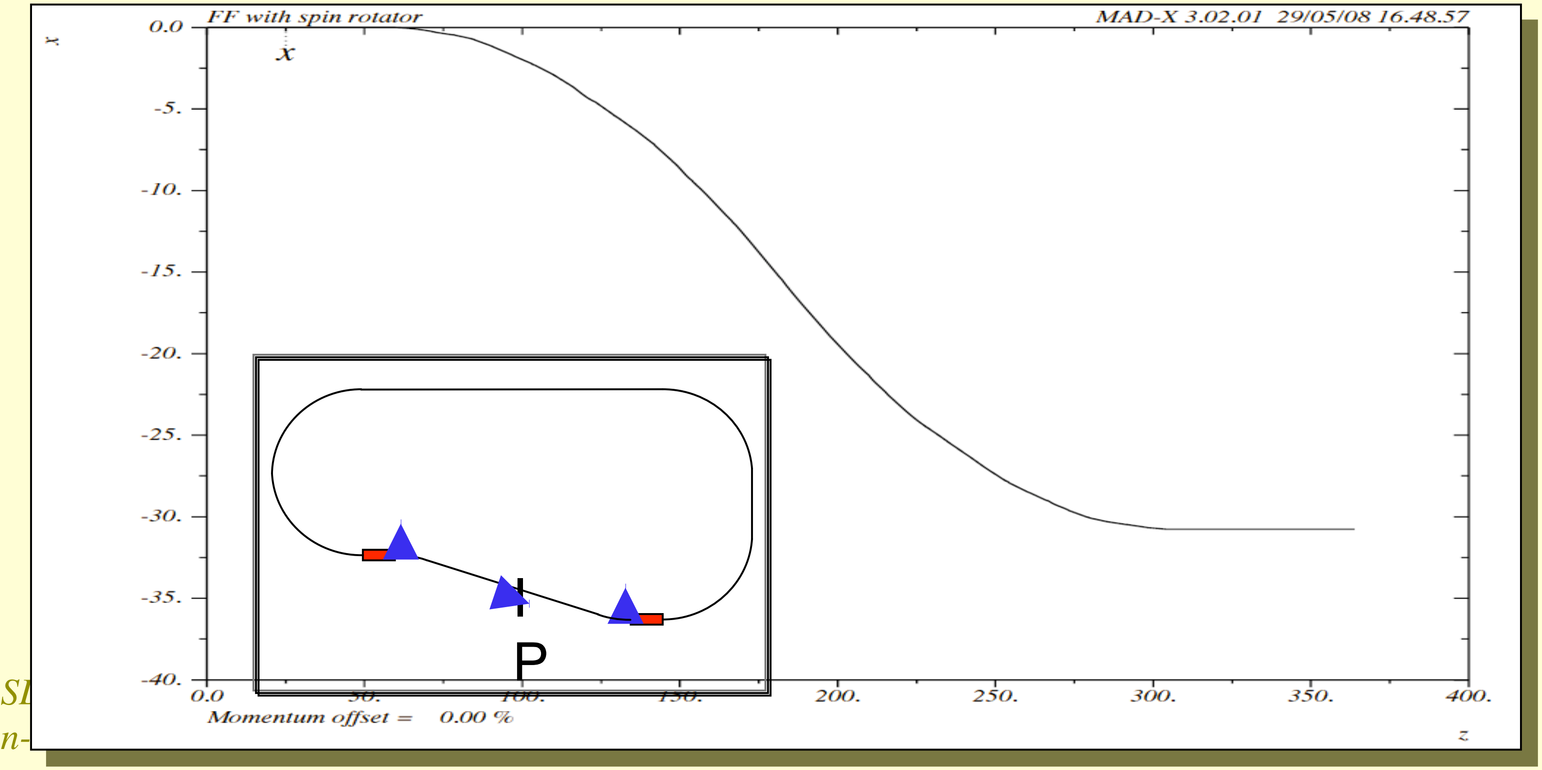


IR with Solenoid Rotator, Layout

Wienands/
W. Wittmer

- Outer s.r. avoids interference with IR optics
  - at a cost of much larger layout change.
- Dipole “hinges” at either end may restore geometry
  - DBA cells => effect on emittance likely very small.

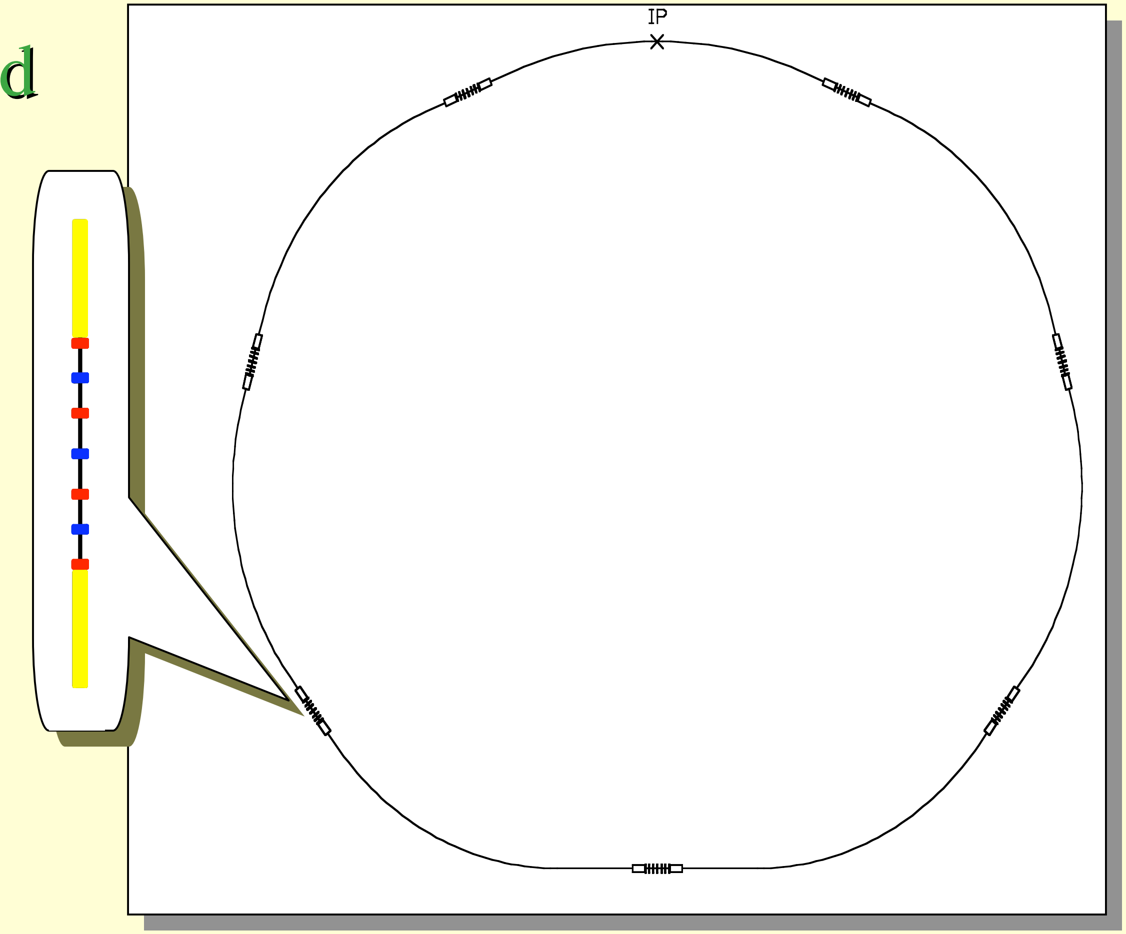
Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up



Layout with 7 Snakes

I. Koop

- Each snake: 180° spin rotator about *z*
- No rotator in IR
- Spin matched
- Polarization independent of energy
- New lattice!



Spin Rotator Summary

U. Wienands

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

Device	Magnets		Solenoid Strength		Dipole Strength		S.R. Length	Ring length	Comment
	Solenoids	Dipoles	Tm (ea.)	Tm (tot)	Tm (ea.)	Tm (tot)	(m, new)	(m, extra)	
Solenoid rotator	4	4	18.3	73.2	1.15	4.6	110	145	Geometry!
Solenoid rotator geom match	4	6	18.3	73.2	1.15	6.9	140	140	
Solenoid w/ spin matching sole.	8	4	18.3	146.4	1.15	4.6	140	140	save 4.6 Tm dipole
Dipole rotator	0	24	0	0	1.15	27.6	200	200	save 4.6 Tm dipole
7 Snakes	14	0	36.6	512.9	0	0	280	0	

Note:

Quads not enumerated

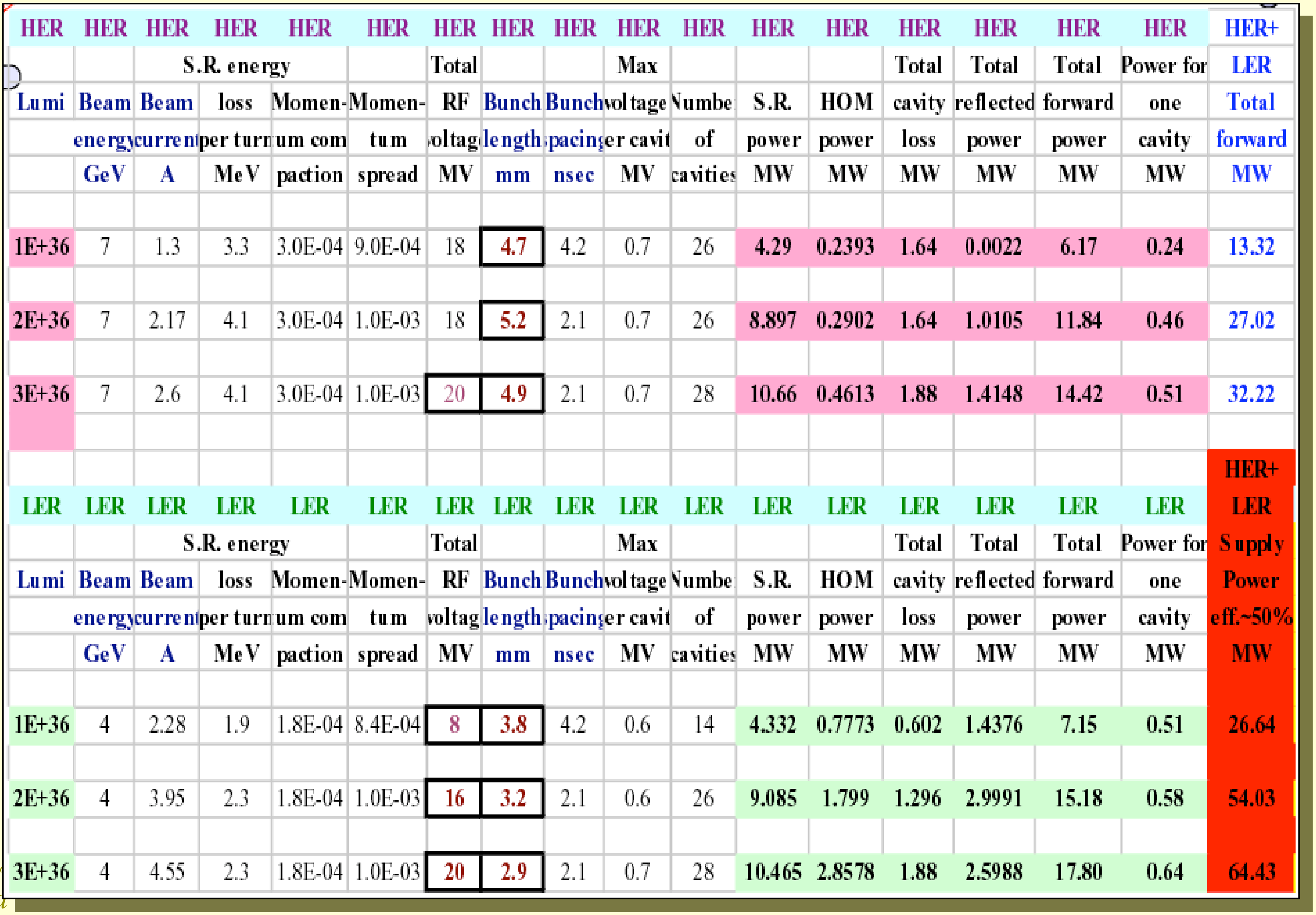
No optics matching considered

- Comments
  - Dipole rotator has v-bends => emittance?
  - Solenoid rotator has plane twister => tuning, emittance?
  - ??? 7 Snakes require √(7) ≈ 2.5 times tuning effort ???

Rf Power Requirement

A. Novokhatski

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up



HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER+
Lumi	Beam energy GeV	Beam current A	S.R. energy loss per turn MeV	Momen- um com paction	Momen- tum spread	Total RF voltag MV	Bunch length mm	Bunch pacing nsec	Max voltage er cavit MV	Numbe of cavities	S.R. power MW	HOM power MW	Total cavity loss MW	Total reflected power MW	Total forward power MW	Power for one cavity MW	LER Total forward MW
1E+36	7	1.3	3.3	3.0E-04	9.0E-04	18	4.7	4.2	0.7	26	4.29	0.2393	1.64	0.0022	6.17	0.24	13.32
2E+36	7	2.17	4.1	3.0E-04	1.0E-03	18	5.2	2.1	0.7	26	8.897	0.2902	1.64	1.0105	11.84	0.46	27.02
3E+36	7	2.6	4.1	3.0E-04	1.0E-03	20	4.9	2.1	0.7	28	10.66	0.4613	1.88	1.4148	14.42	0.51	32.22

LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+ LER
Lumi	Beam energy GeV	Beam current A	S.R. energy loss per turn MeV	Momen- um com paction	Momen- tum spread	Total RF voltag MV	Bunch length mm	Bunch pacing nsec	Max voltage er cavit MV	Numbe of cavities	S.R. power MW	HOM power MW	Total cavity loss MW	Total reflected power MW	Total forward power MW	Power for one cavity MW	Supply Power eff.~50% MW
1E+36	4	2.28	1.9	1.8E-04	8.4E-04	8	3.8	4.2	0.6	14	4.332	0.7773	0.602	1.4376	7.15	0.51	26.64
2E+36	4	3.95	2.3	1.8E-04	1.0E-03	16	3.2	2.1	0.6	26	9.085	1.799	1.296	2.9991	15.18	0.58	54.03
3E+36	4	4.55	2.3	1.8E-04	1.0E-03	20	2.9	2.1	0.7	28	10.465	2.8578	1.88	2.5988	17.80	0.64	64.43

Touschek Simulation LER

M. Boscolo

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

LER Touschek particles lost at IR

NO COLLIMATORS inserted

Touschek lifetime ≈ 24 min

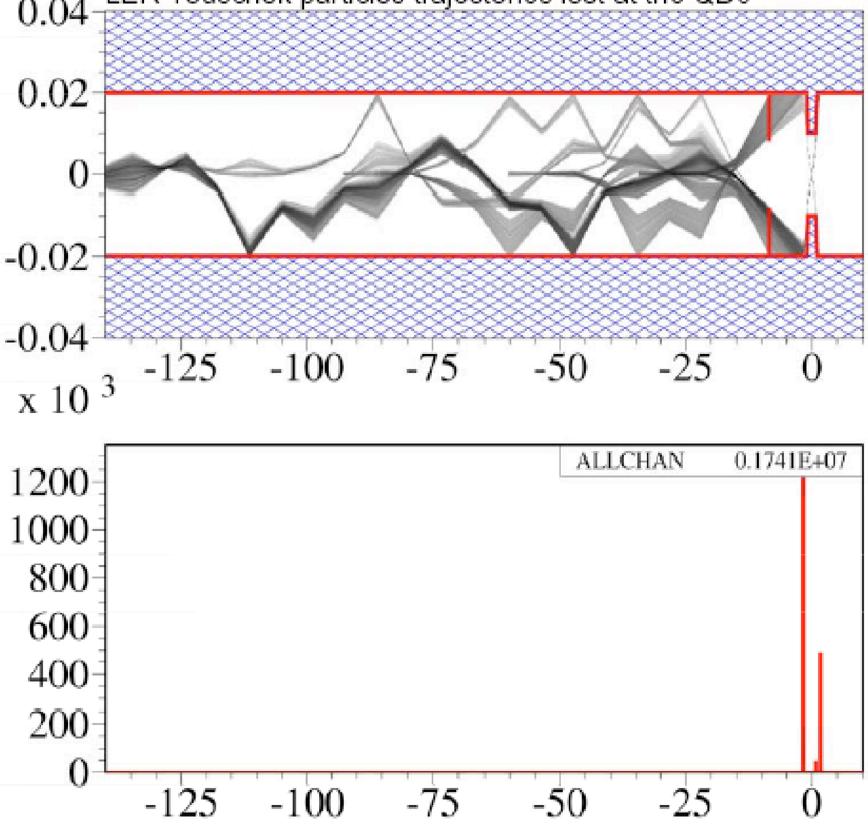
$\Delta E/E$ = 0.1% - 4%

rf accept. =2.9 %

machine turns = 5

K=0.25%

ε_x=2.8 nm ; σ_z=5 mm


example of
LER Touschek particles trajectories lost at the QD0

IR Losses (|S|<2m)= 1.7 MHz

for 1 bunch with I_{bunch} =1.49 mA

IR Losses (|S|<2m)= 2.1 GHz

at full current

Touschek Simulation HER

M. Boscolo

Facility

Crab Waist

Accelerators

IR

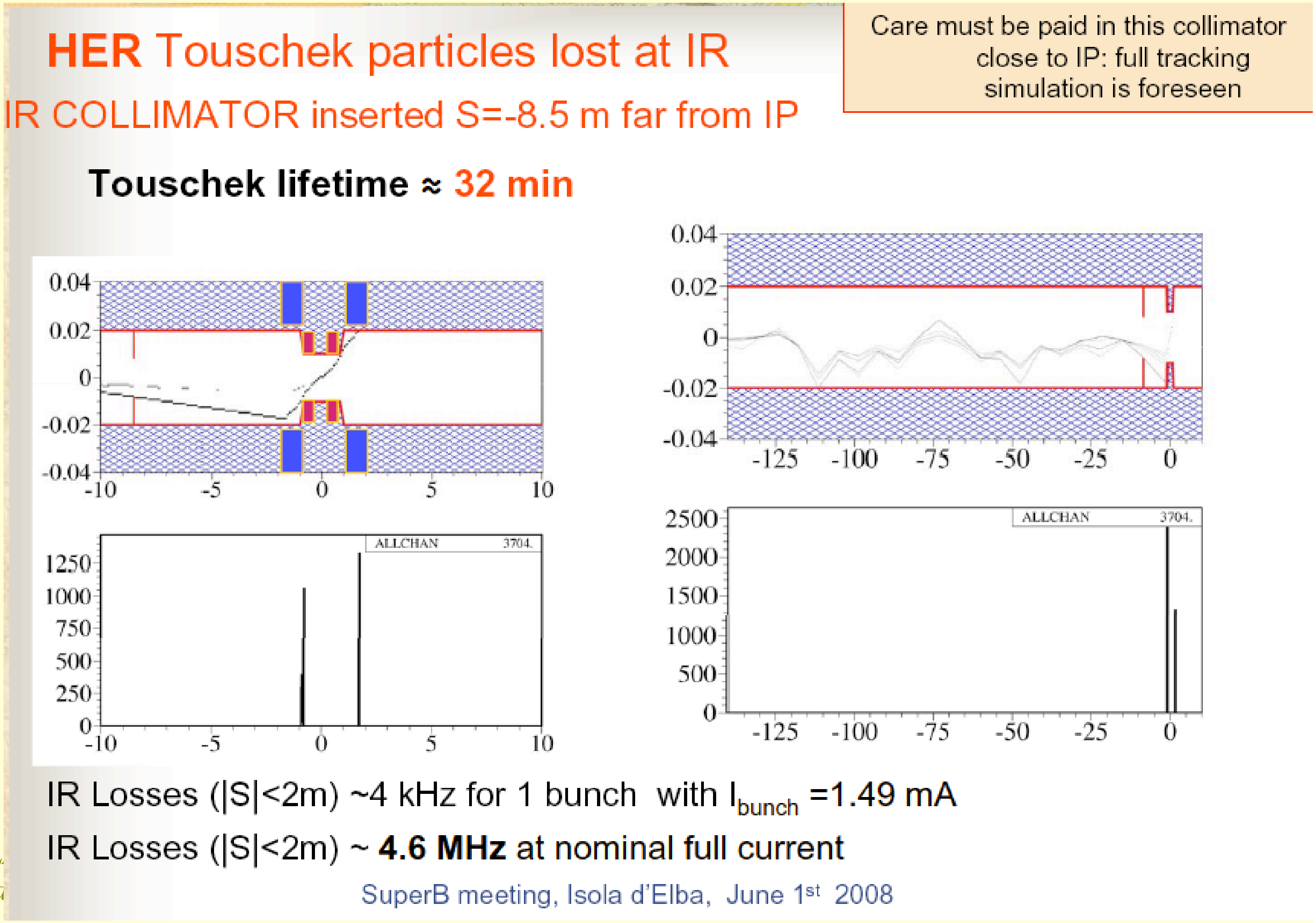
Polarization

Intensity

Feedbacks

Injector

Wrap-Up



HER Touschek particles lost at IR

IR COLLIMATOR inserted S=-8.5 m far from IP

Care must be paid in this collimator close to IP: full tracking simulation is foreseen

Touschek lifetime ≈ 32 min

IR Losses (|S|<2m) ~4 kHz for 1 bunch with I_{bunch} =1.49 mA

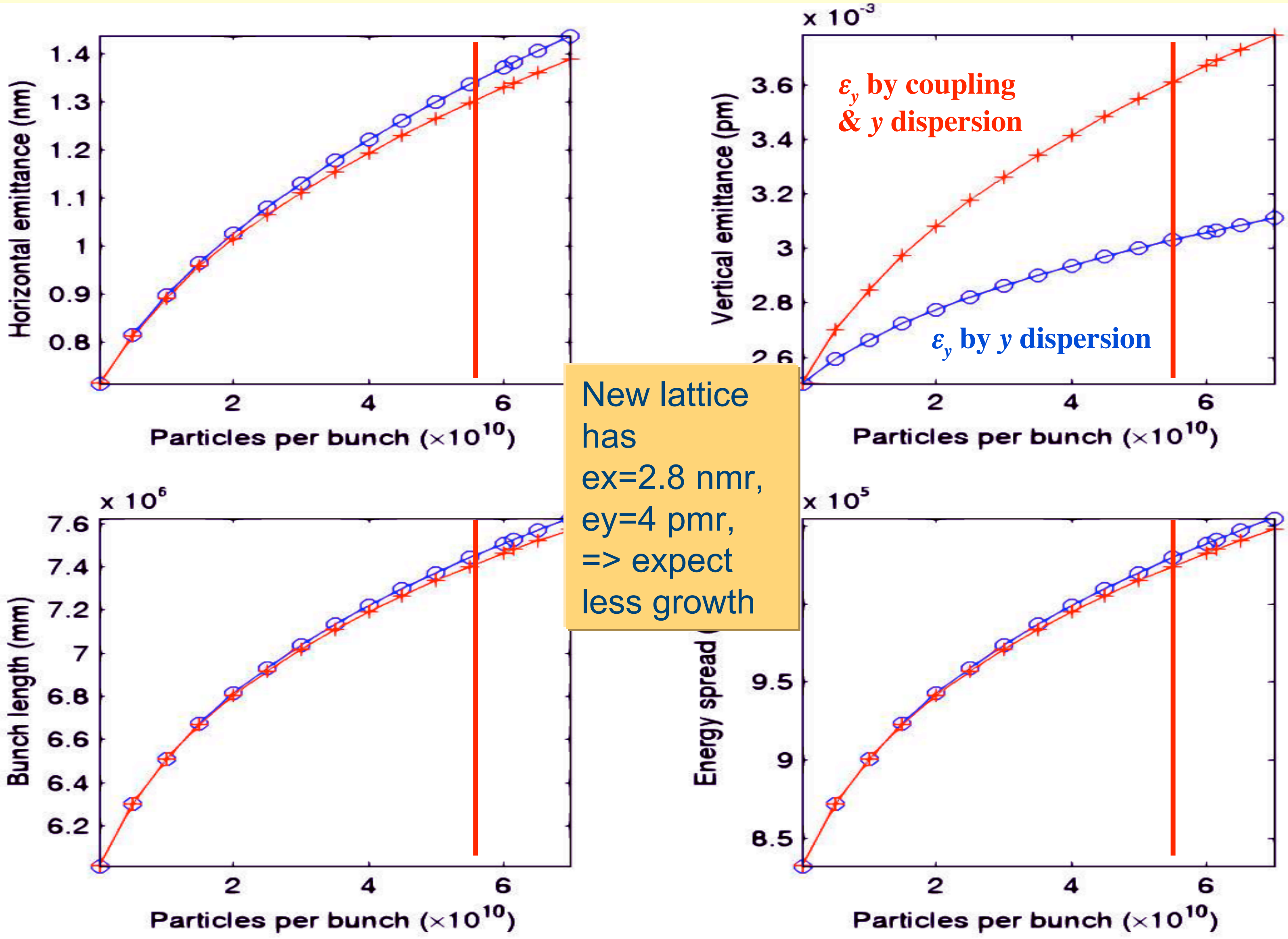
IR Losses (|S|<2m) ~ **4.6 MHz** at nominal full current

SuperB meeting, Isola d'Elba, June 1st 2008

IBS (Super*B* LER)

A. Wolski, Liverpool, Super*B* CDR.

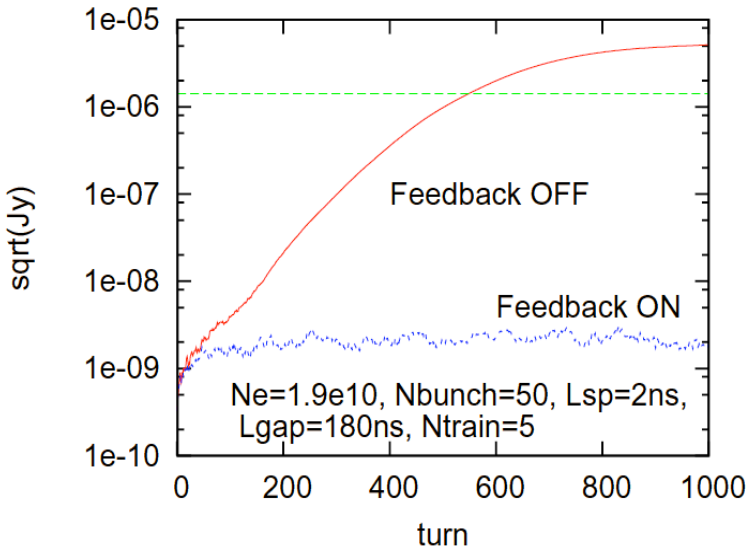
- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up

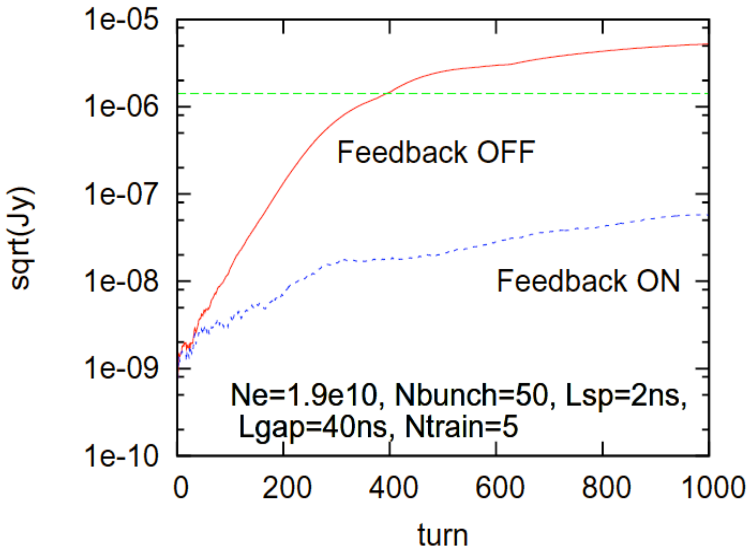


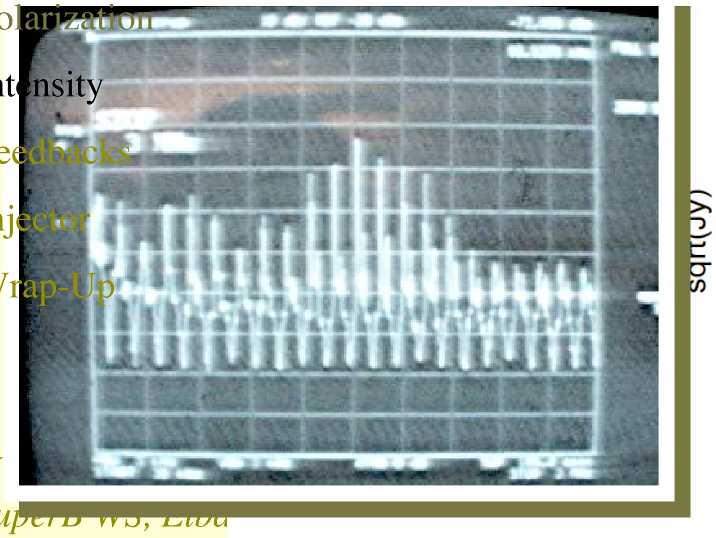
New lattice has ex=2.8 nmr, ey=4 pmr, => expect less growth

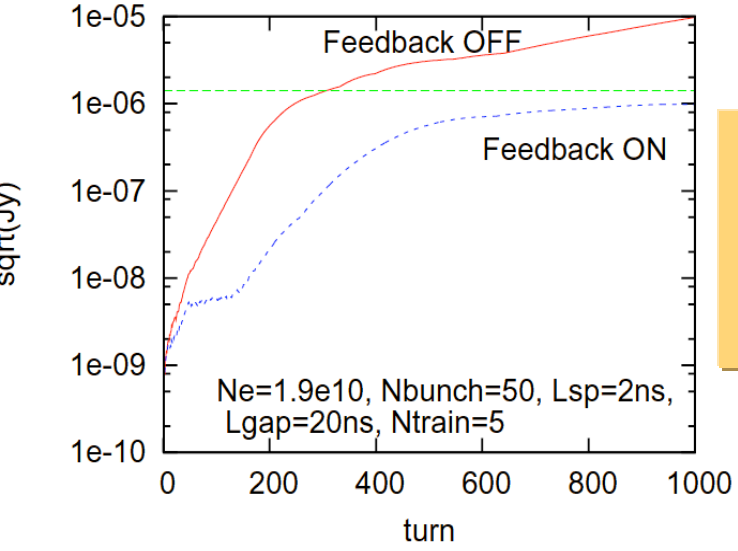
Ions in Super*B* HER

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up









0.25 nTorr pressure

beam of bunch trains

1.9×10^{10} ppb

Ions in SuperKEKB LER (a long train)

H. Fukuma

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

Energy 3.5 GeV

Bunch spacing : 2ns (=0.6m)

Number of bunch : 5120

Bunch current : 1.9 mA

Pressure : 1 nTorr (CO)

Emittance (H/V) : 24 nm/0.96 nm

Beam size (H/V) : 0.6 mm/0.12 mm

Beta function (H/V) : 15 m/15 m

Tune(V) : 43.545

Q : 10

(revolution time : 10 μs)

$$\omega_\beta = 2.72\,10^7 \sec^{-1}$$

$$\omega_i = 1.23\,10^8 \sec^{-1}$$

$$\lambda_{ion} = 806\, m^{-1} \text{ (per bunch)}$$

$$\phi_{ion} = \omega_i \cdot s_B / c = 0.246$$

$$\kappa = 8.53\,10^{-9} m^{-3}$$

$$\alpha = \frac{\omega_i}{2Qc} = 0.0205$$

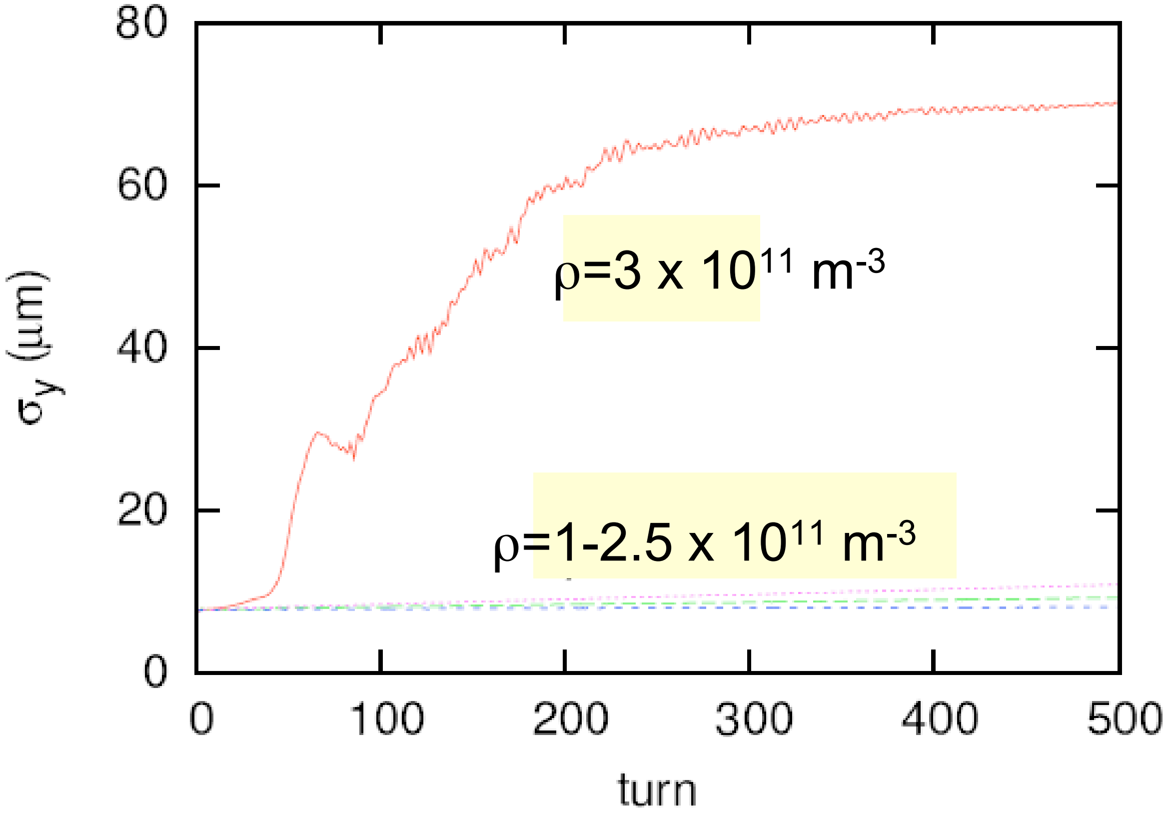
$$\underline{\tau_e = 2\tau\ell\alpha = 2.3\ \mu s}$$

less than one turn

Electron Cloud Instability

K. Ohmi, KEK

Emittance growth from single-bunch instability driven by electron cloud in the SuperB positron ring (nominal parameters of the 2.25 Km LER). Instability threshold set tolerances on maximum allowed SEY.



Considering R&D feedback for low emittance accelerators

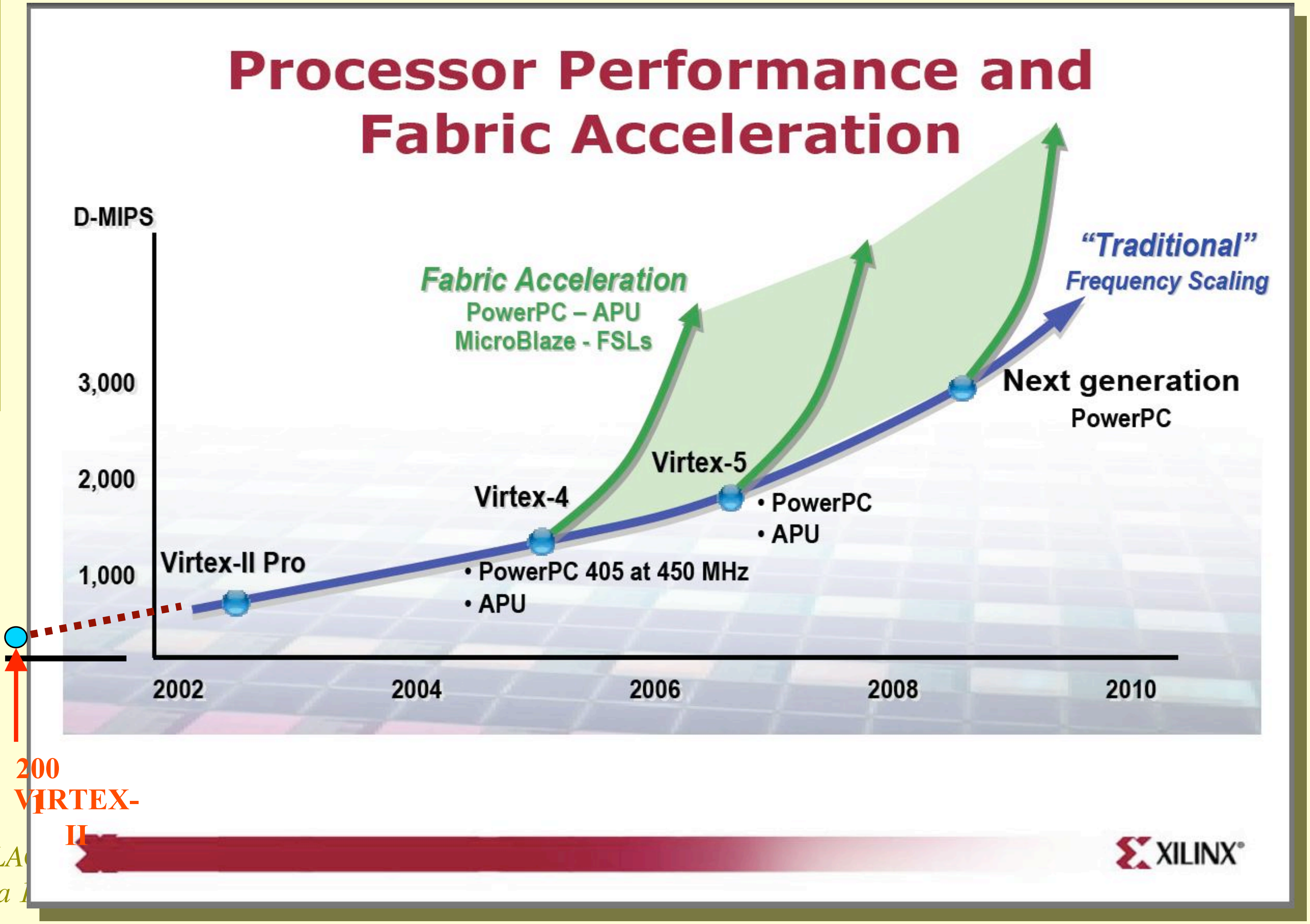
A. Drago

- The R&D list for an upgrade starting **from iGp**-like system (in the software & gateware version running at the present at DAFNE) includes:

1) very low noise analog front end @ 3*RF
2) maintain low cross-talk between adjacent bunches under 40 dB (better 60 dB)
3) dual separated timing to pilot the backend power stage
4) digital block with higher dynamic range (12/16bits)
5) "dual gain" approach to minimize residual beam motion
6) integrated beam-feedback model

A. Drago

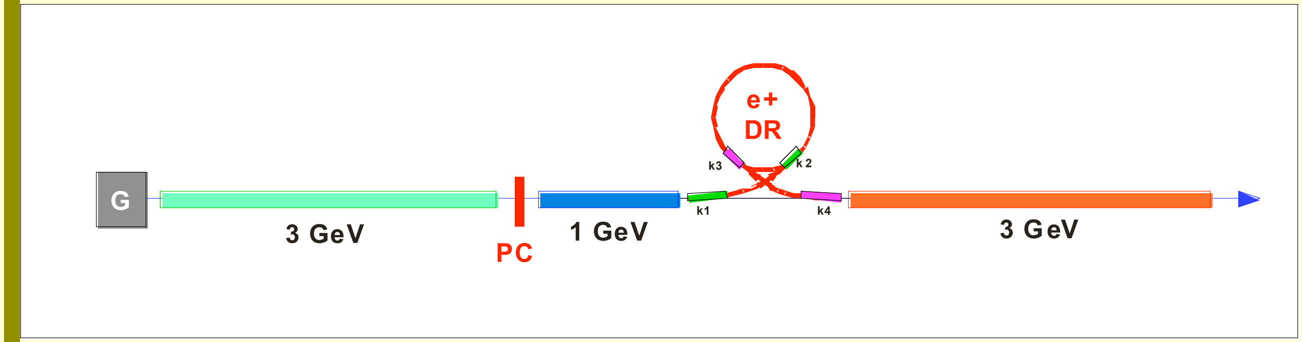
- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- **Feedbacks**
- Injector
- Wrap-Up



Processor Performance and Fabric Acceleration

INJECTOR SCHEMATIC LAYOUT

R. Boni



e+ 4 Gev

e- 7 Gev

- Facility
- Crab Waist
- Accelerators
- IR
- Polarization
- Intensity
- Feedbacks
- Injector
- Wrap-Up

Linac → s-band (2856 MHz) - room-temperature

e+ damping ring → 1.2 GeV – 35 mt circumference

(could be the SLC e+ DR)

Note: no e^- DR

=> need polarized rf gun

RF Power Station layout comparison

R. Boni

Facility

Crab Waist

Accelerators

IR

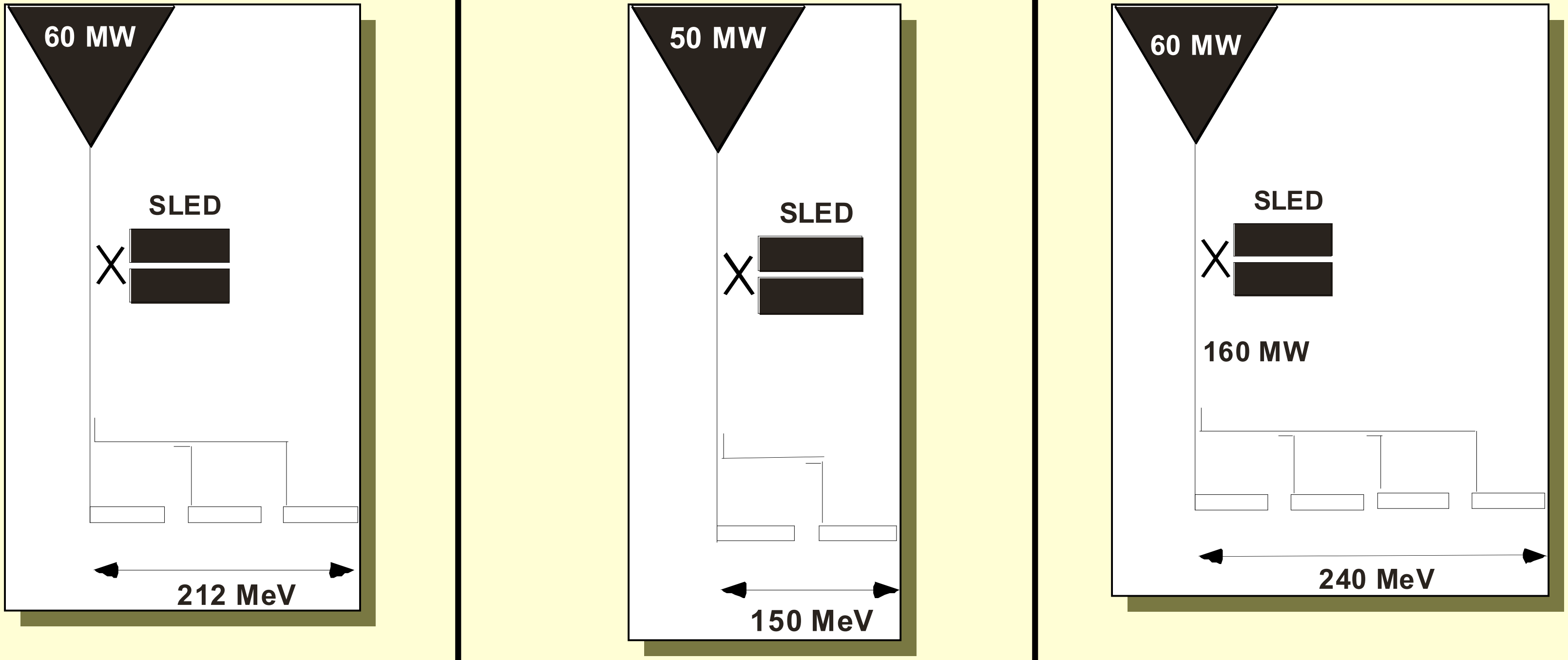
Polarization

Intensity

Feedbacks

Injector

Wrap-Up



36 power stations
108 acc. structures
active length 324 m.
gradient 23.5 MV/m

49 power stations
98 acc. structures
active length 294 m.
gradient 25 MV/m

31 power stations
124 acc. structures
active length 372 m.
gradient 20 MV/m

Some Accelerator Priority Items

- "Default Parameter set" <= Settle Lattice
  - – Decide on spin handling & rotator type.
  - – Spin rotator tail may wag the SuperB dog!
    - Ring layout, IR Design (optics & s.r. handling)
- Keep pressing on beam-beam understanding
    - DAFNE MDs, simulations, …
- Continue tracking studies & optimization of lattice
- Continue studying e-cloud, ions etc.
- Injector definition:
  - – e^-(pol.) source parameters? e^- DR needed? Spin handling, e^+ targetry, linac(s), …

List of Issues to Work…(1/3)

M. Biagini

- Spin rotator:
  - choose a scheme (since FF seems to be optimized, not good to insert spin rotator inside FF)
  - matching into ring lattice
  - repeat DA studies with s.r.
  - is spin matching necessary?
  - spin tracking code (Barber ?) → after
  - …

- Beam-beam simulations:
  - Perform full scan of tunes plane with checks on DA (Shatilov-Piminov codes)
  - Vertical tune shift
  - Beam-beam tails → emittance growth
  - Codes?
  - ….

List of Issues to Work…(2/3)

M. Biagini

- Present lattice without spin rotator: good DA for HER (LER not computed yet), good Final Focus from backgrounds studies. Next:
  - DA for both rings
  - DA with errors (magnets and alignment)
  - Tracking of injected beam with larger ε
  - Lattice acceptance w.r.t. injected beam
  - Injection scheme
  - Application of Normal Forms
  - Definition of geometry of the region where rings cross (opposite to FF)
  - Layout for LER & HER
  - Geometry of IR
  - Detector solenoid compensation & coupling correction scheme
  - Mechanical layout
  - …

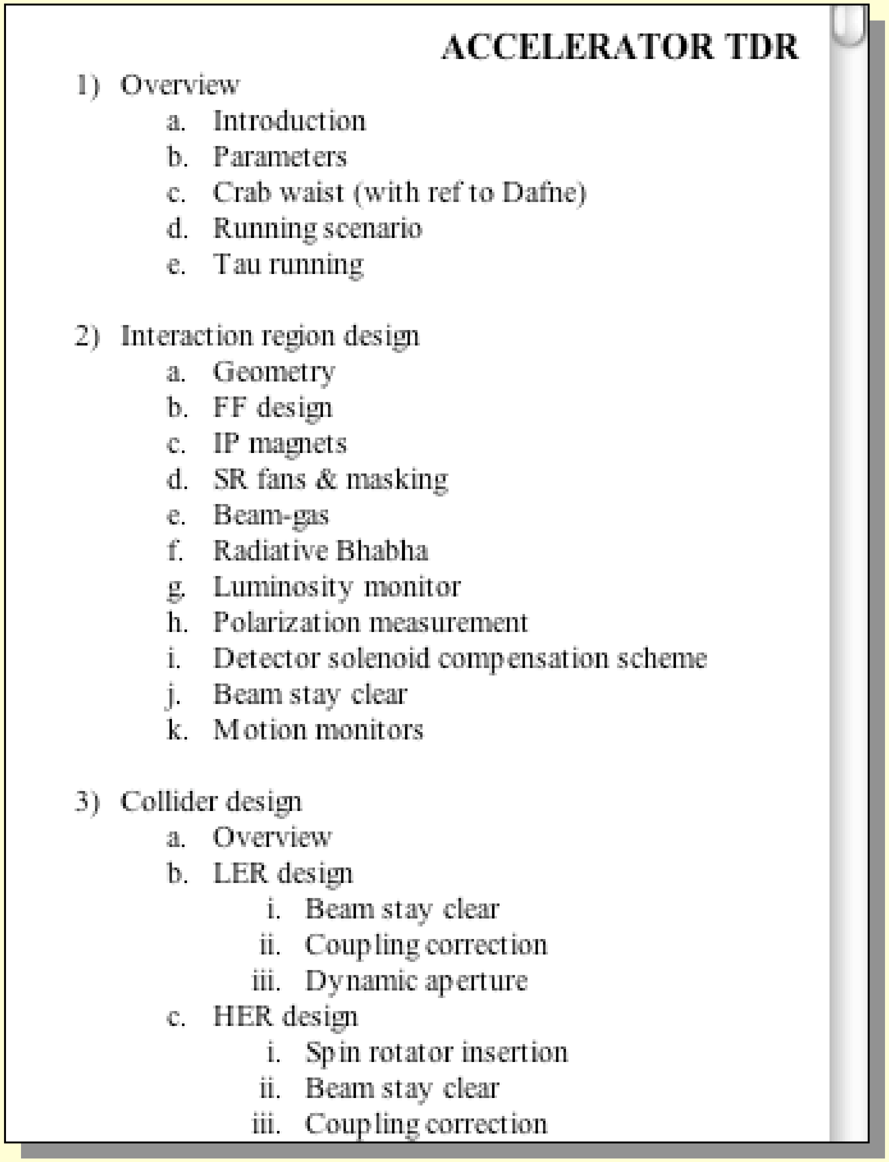
List of Issues to Work…(3/3)

M. Biagini

- Beam dynamics & instabilities (in order of importance):
  - E-cloud (simulation started)
  - Fast ion
  - IBS
  - RF
  - Space charge
  - Multibunch
  - CSR
  - Touschek (preliminary work done, collimators and/or masks to be studied)
  - ….
- Emittance tuning procedures

Towards the Accelerator TDR

- Draft TOC
- 1st estimate of resources needed to complete TDR.
  - Not an unreasonable number compared to potentially available resources…
  - to be negotiated…
- We would like to settle the footprint in 6 mo., finish the TDR in 18 mo.
- **Help is welcome!**



ACCELERATOR TDR

1) Overview
    a. Introduction
    b. Parameters
    c. Crab waist (with ref to Dafne)
    d. Running scenario
    e. Tau running

2) Interaction region design
    a. Geometry
    b. FF design
    c. IP magnets
    d. SR fans & masking
    e. Beam-gas
    f. Radiative Bhabha
    g. Luminosity monitor
    h. Polarization measurement
    i. Detector solenoid compensation scheme
    j. Beam stay clear
    k. Motion monitors

3) Collider design
    a. Overview
    b. LER design
        i. Beam stay clear
        ii. Coupling correction
        iii. Dynamic aperture
    c. HER design
        i. Spin rotator insertion
        ii. Beam stay clear
        iii. Coupling correction

Facility
Crab Waist
Accelerators
IR
Polarization
Intensity
Feedbacks
Injector
Wrap-Up

It remains my privilege to thank INFN for hosting this most exciting workshop and to look forward to an intense and fruitful collaboration!

The ~~End~~ Beginning!