Beam lifetime and backgrounds simulation studies at SuperB

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2nd SuperB Collaboration Meeting @ INFN-LNF
December 13th – 16th 2011

Dominant effects on backgrounds and lifetime

Two colliding beams

- Radiative Bhabha $\rightarrow$ dominant effect on lifetime and backgrounds
- Pairs Production

Single beam

- Synchrotron Radiation
- **Touschek**
- **Beam-gas**
- Intra-beam scattering

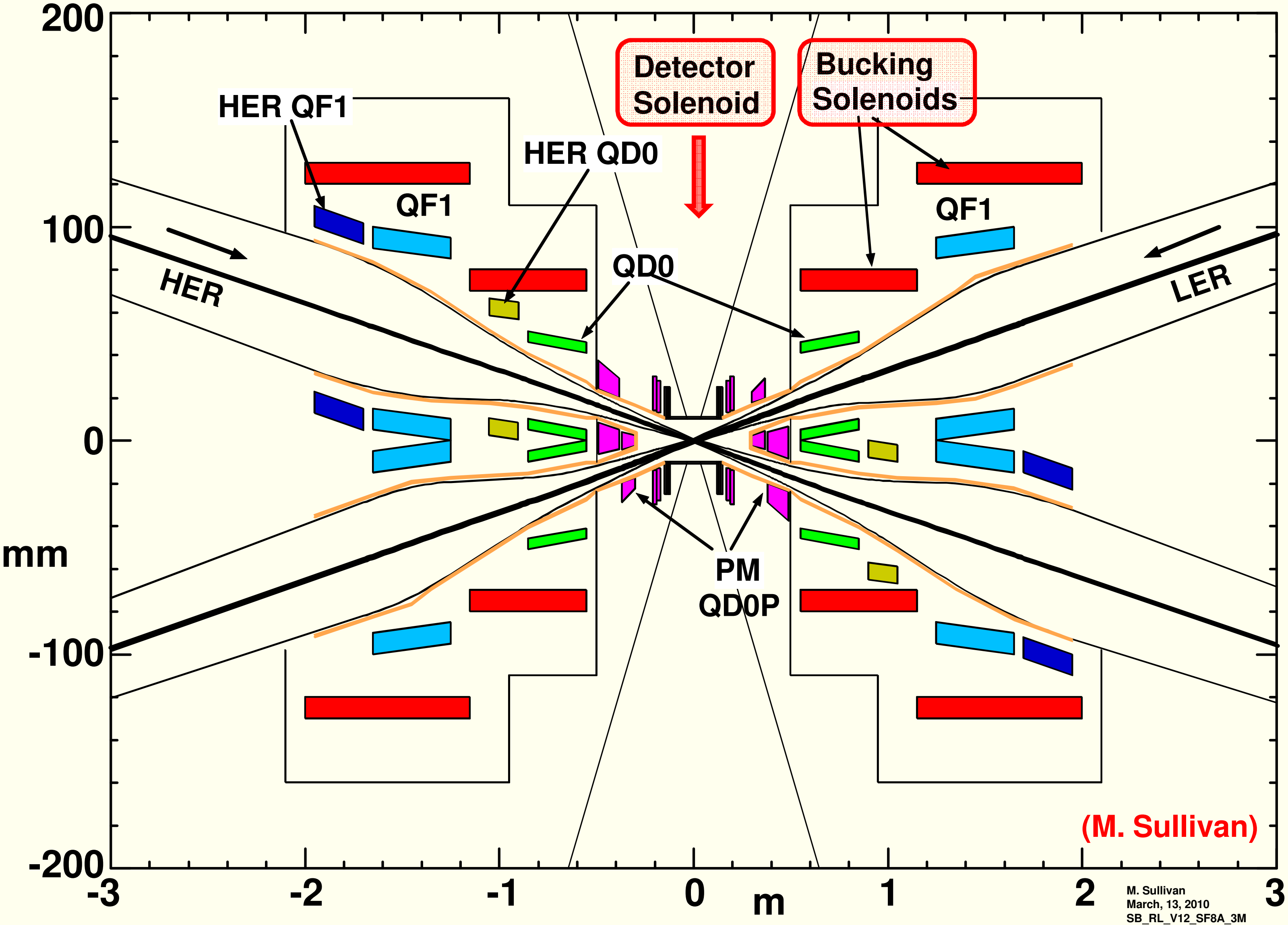
Outline

- The main sources of loss rates are under control and secondaries tracked into sub-detectors and their effects evaluated (many dedicated talks in Parallel sessions). Simulations get more and more realistic

- A new campaign of background simulations is planned as the latest lattice V16 will be *frozen* including an updated design of the Interaction Region
  (+ Cryostat constraints)

- **Update on Touschek and beam-gas lifetime & loss rates estimates for**
  V12 lattice with *realistic* IR layout from M. Sullivan
  (optics with the whole ring rematched, PAC11)

IP region
Air core "Italian" QD0, QF1



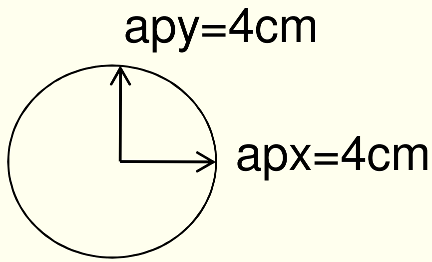
Just updated

Simulation results

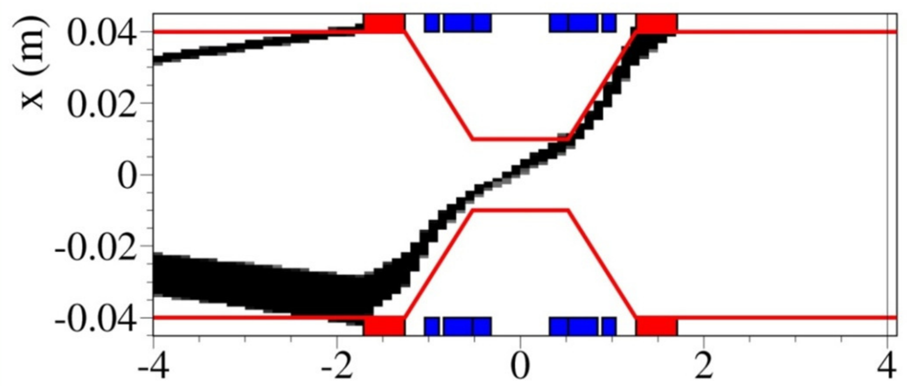
Presented in ELBA, June 2011

stable results with few machine turns and about 10^6 macroparticles

- Calculated lifetime and rates are dependent on the:
  - *lattice* energy acceptance
  - physical aperture -elliptical shape
  - Dynamical aperture accounted for with non-linear elements in tracking



- Half vertical aperture = 4 cm everywhere
- Half horizontal aperture = 4 cm everywhere but at the IR
  - at QF1 BSC >~ 30 σ_x



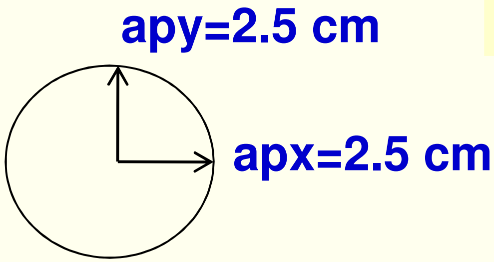
Simulation results need to be updated together with IR design

DONE!

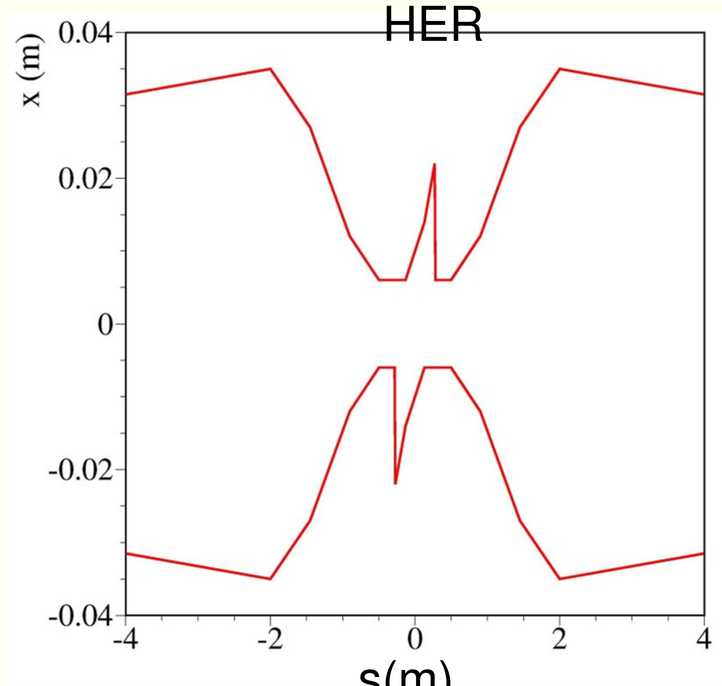
Physical aperture

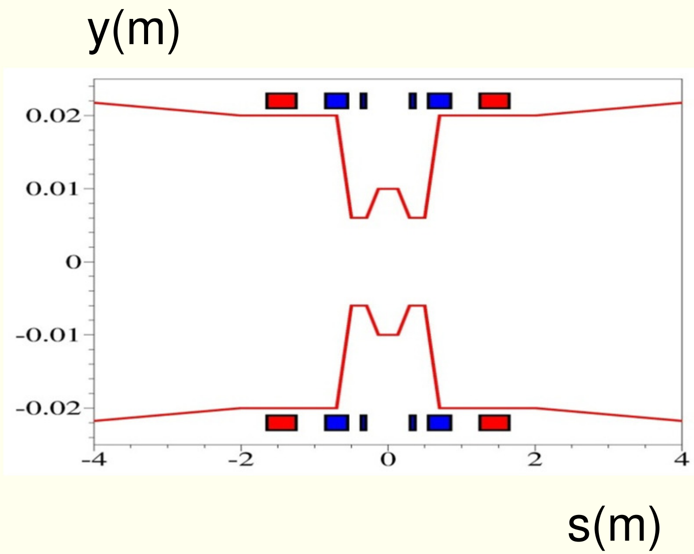
While a new optics (V16, see Pantaleo's talk yesterday) is getting more and more solid and self-consistent, we go on in modelling better the machine

- circular pipe

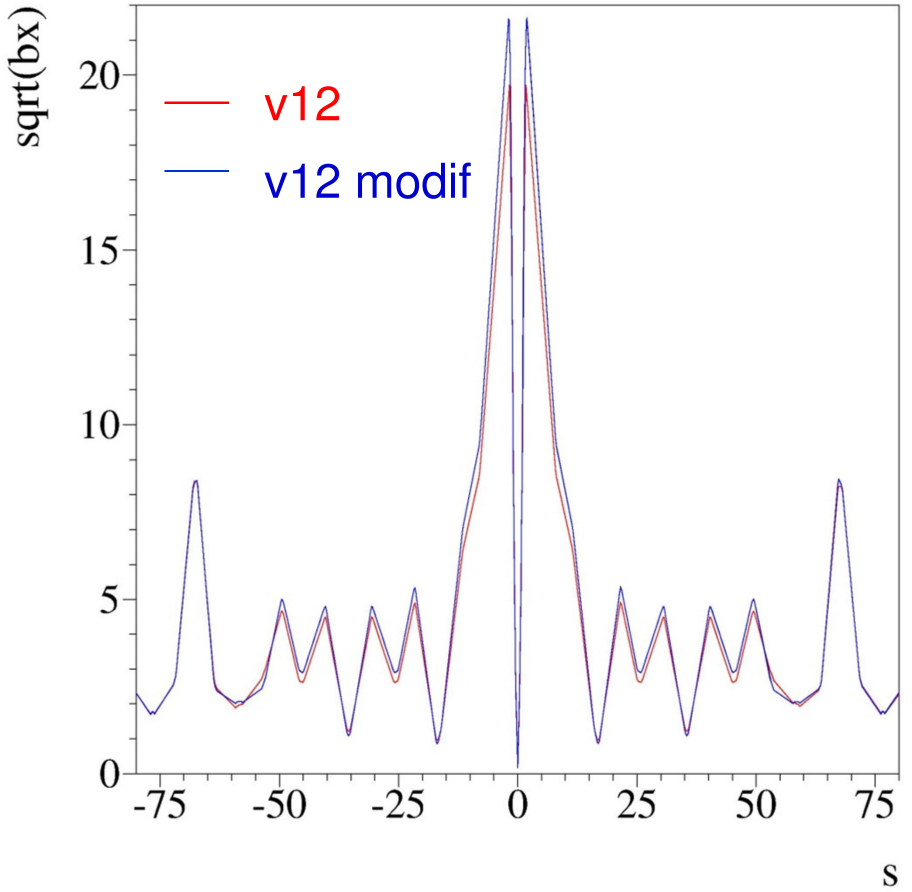


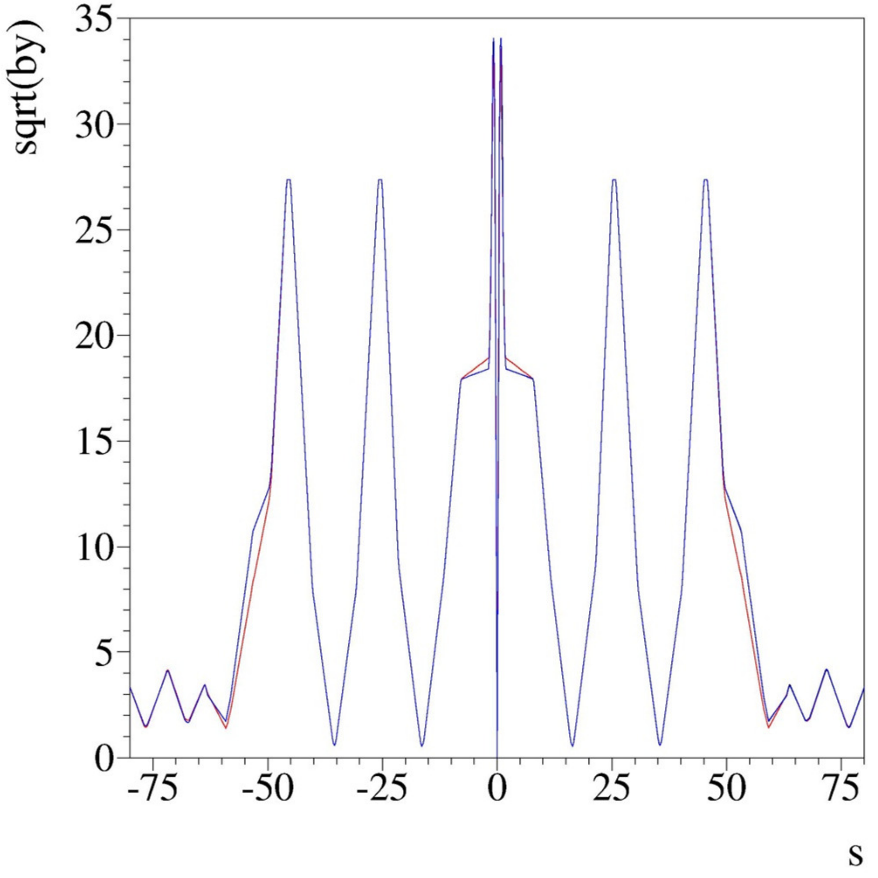
- Half vertical aperture = **2.5 cm everywhere BUT AT IR**
- Half horizontal aperture = **2.5 cm everywhere but at the IR**





HER Optics: zoom of Final Focus

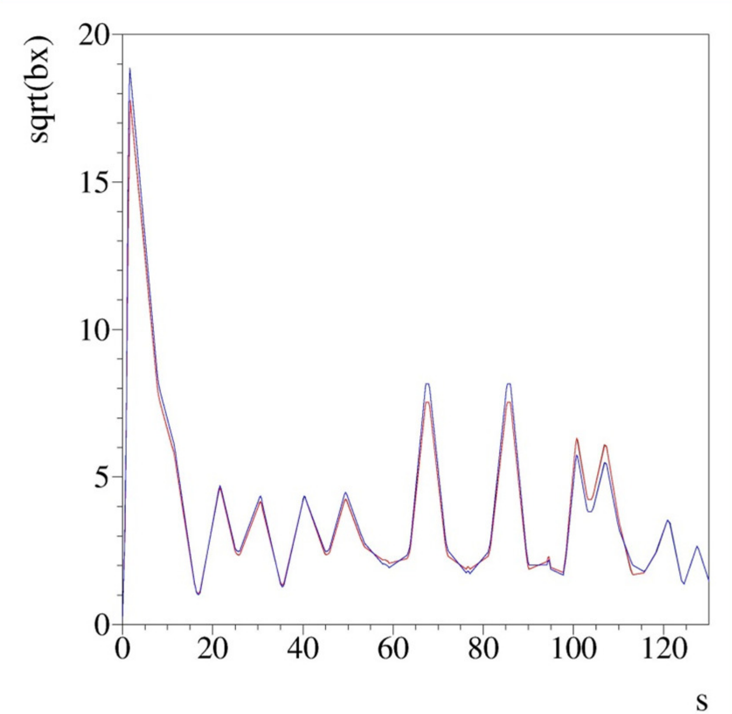


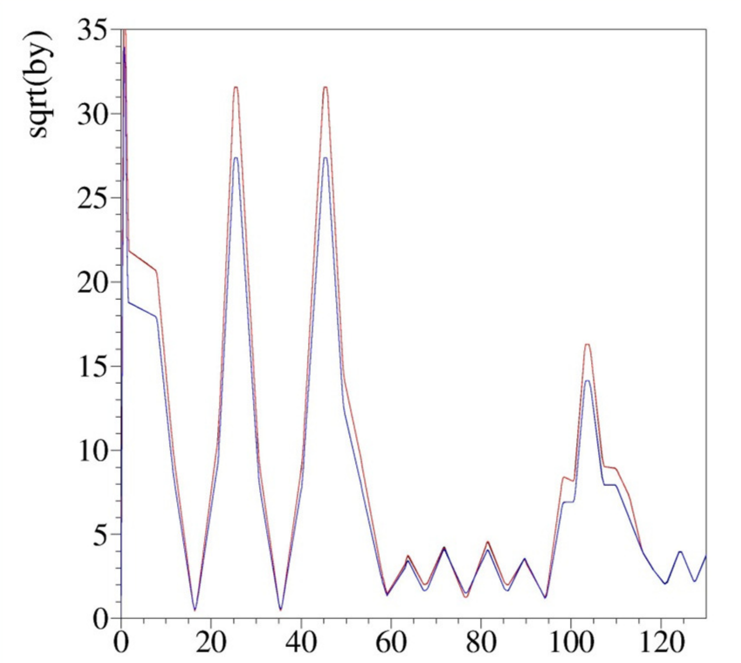


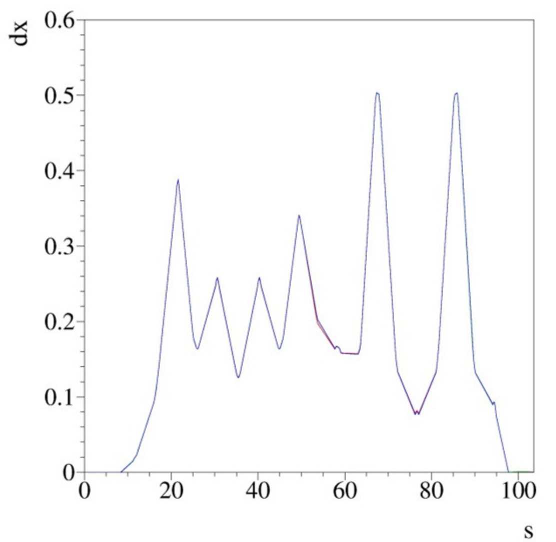
beta_x* = 2.6cm
beta_y* = 0.27mm

beta_x* = 2.6cm
beta_y* = 0.27mm

LER Optics: Final Focus







—— v12	beta_x* = 3.2cm beta_y* = 0.206mm	Nominal values

—— v12 modif beta_x* = 2.6cm
beta_y* = 0.274mm

Modif. V12 HER Touschek Lifetime

V12 lattice+ more realistic aperture	τ_{TOU} (min)
No collimators	**26**
Optimal set of horizontal Collimators	**22**

~1.2 lifetime reduction
to greatly reduce IR losses

v12 HER Touschek Lifetime

V12 lattice	τ_{TOU} (min)
No collimators	**40**
Optimal set of horizontal Collimators	**33**

~1.2 lifetime reduction
to greatly reduce IR losses

Modif. V12 LER Touschek Lifetime

collimators setting	ε_x (m rad)	τ_{TOU} (s)	τ_{TOU} (min)
No collimators	1.8e-9 , no IBS	**447**	**7.4**
No collimators	2.4e-9, with IBS	**611**	**10.2**
With collimators	2.4e-9, with IBS	**472**	**7.9**

~ 1.3 lifetime reduction
to greatly reduce IR losses

v12 **LER** Touschek Lifetime

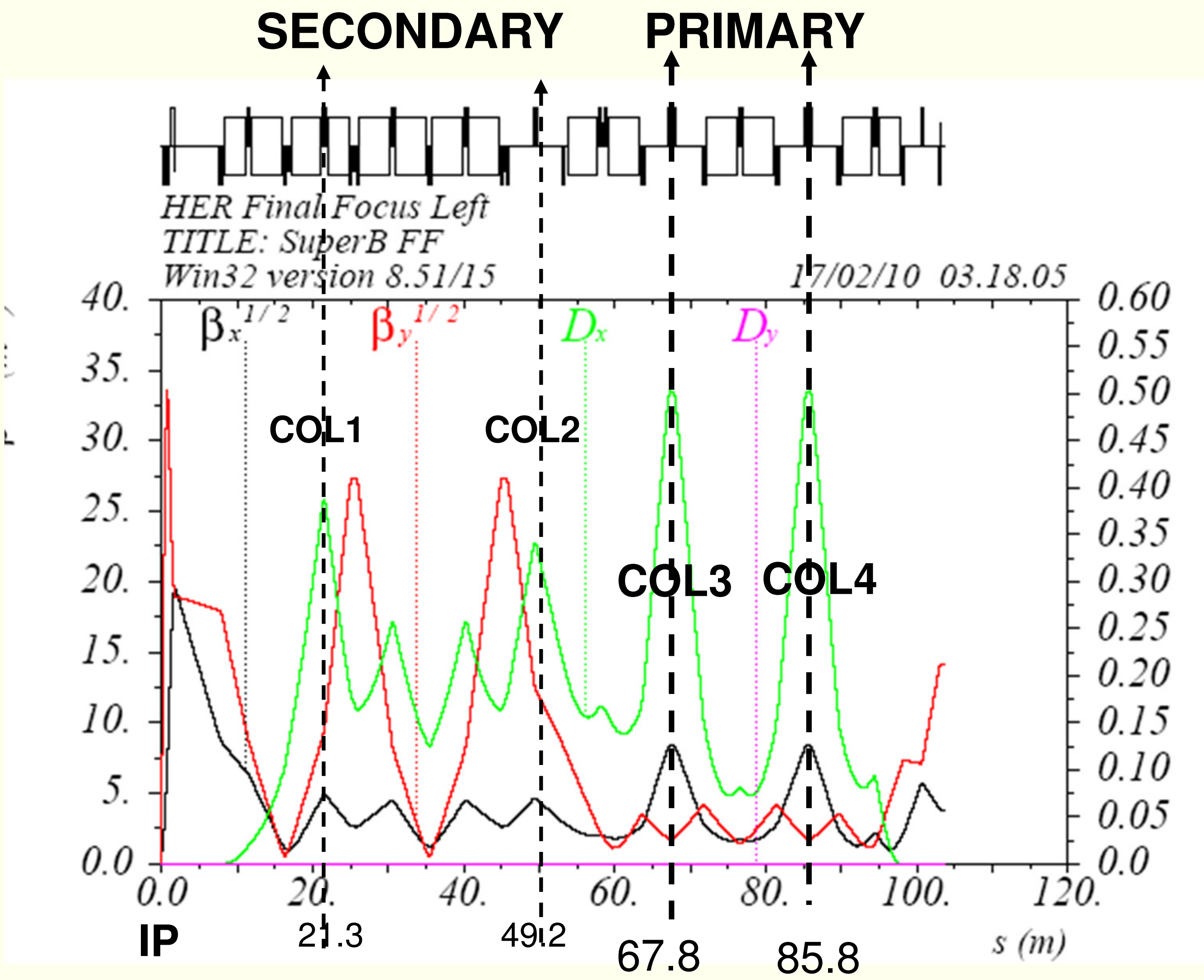
collimators setting	ε_x (m rad)	τ_{TOU} (s)	τ_{TOU} (min)
No collimators	1.8e-9 , no IBS	**350**	**5.9**
No collimators	2.4e-9, with IBS	**460**	**7.8**
With collimators	2.4e-9, with IBS	**400**	**6.6**

1.2 lifetime reduction
to greatly reduce IR losses

Short Touschek lifetime, but not the limiting effect-however it needs special care, especially because most of particle losses tend to be at the IR

HER / LER Final Focus collimation system

Collimators are located where βx and Dx are large



Horizontal Collimators upstream the IR

Intercept the Touschek particles in the final focus upstream the IR that otherwise would be lost at the QF1

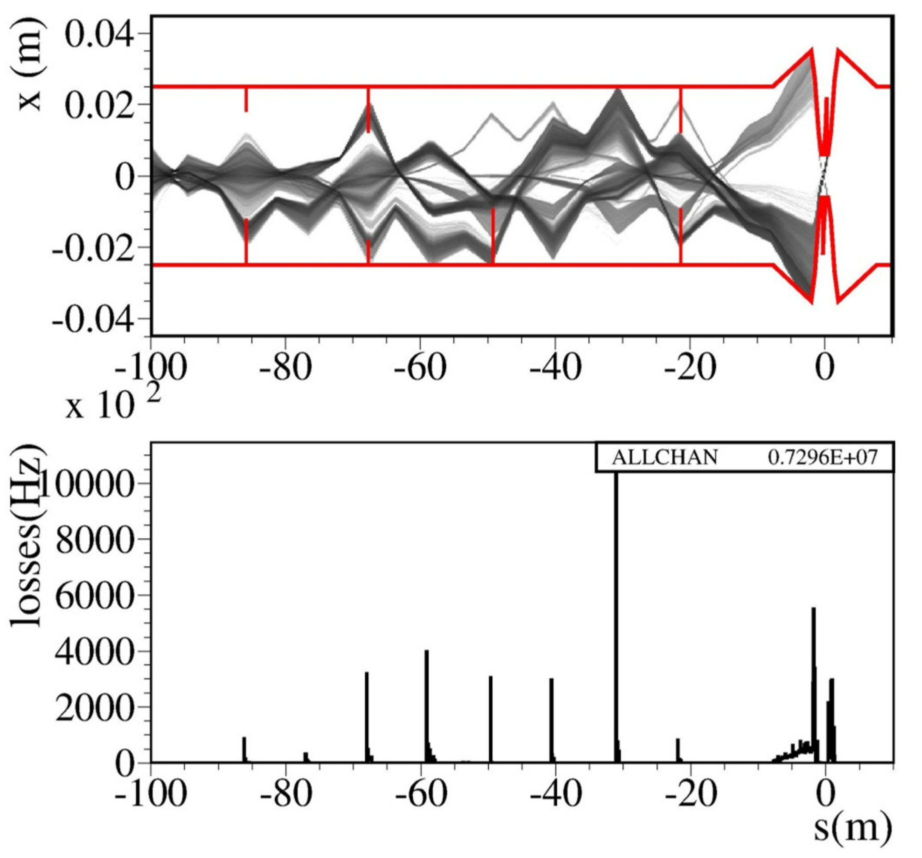
So, in principle, the good collimators set corresponds to the same Beam Stay Clear , in sigmax units, that we have in the IR

Collimator jaw insertion = 0.9^* phys. aperture(QF1)$\cdot\sigma_{COL} / \sigma_{QF1}$

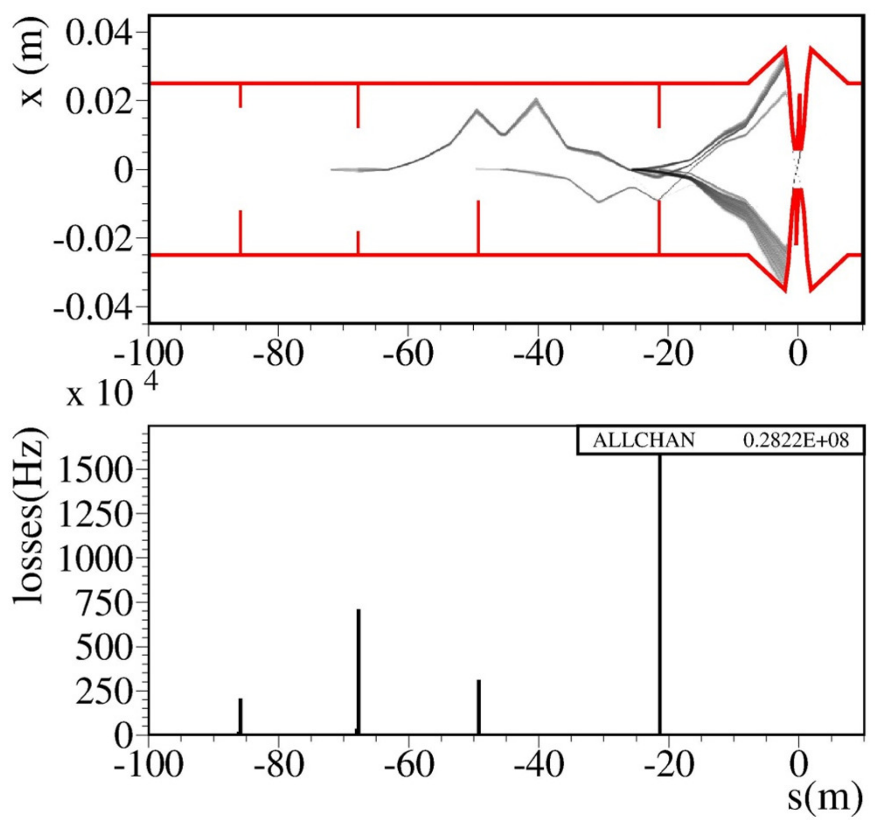
This has been the initial jaw opening, the optimal position has been found in the simulations

HER v12modif   Touschek Trajectories

No collimators



with collimators



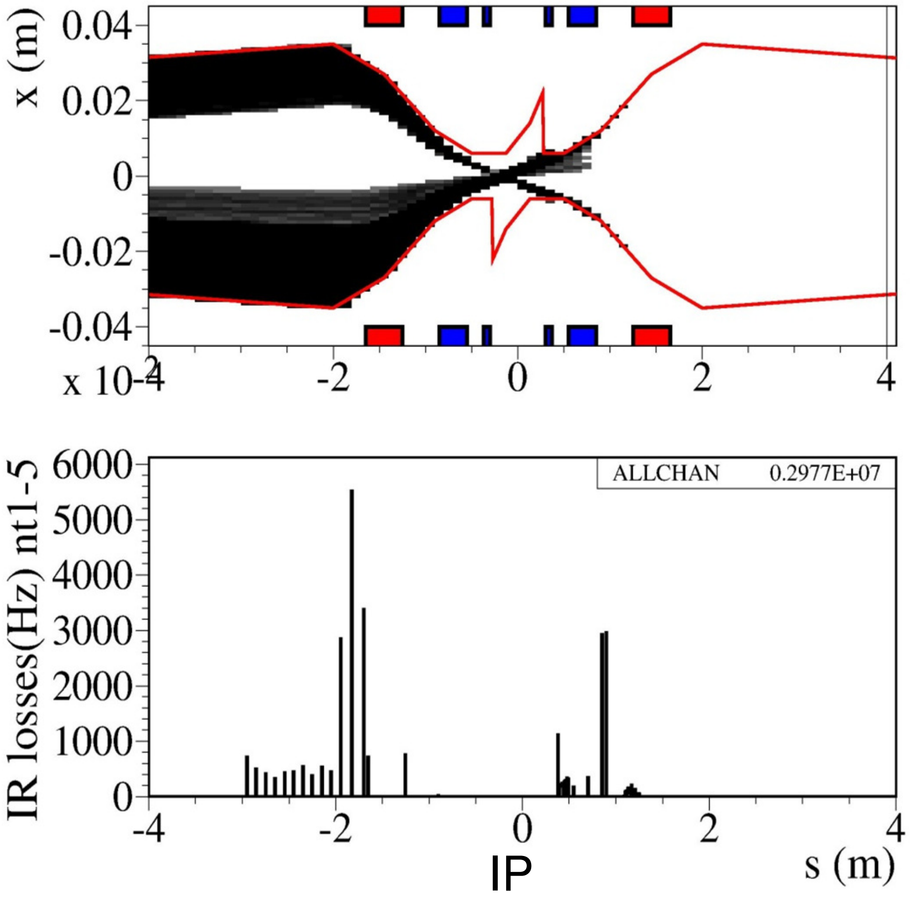
found by minimizing IR rates and maximizing lifetime

real set will be found experimentally

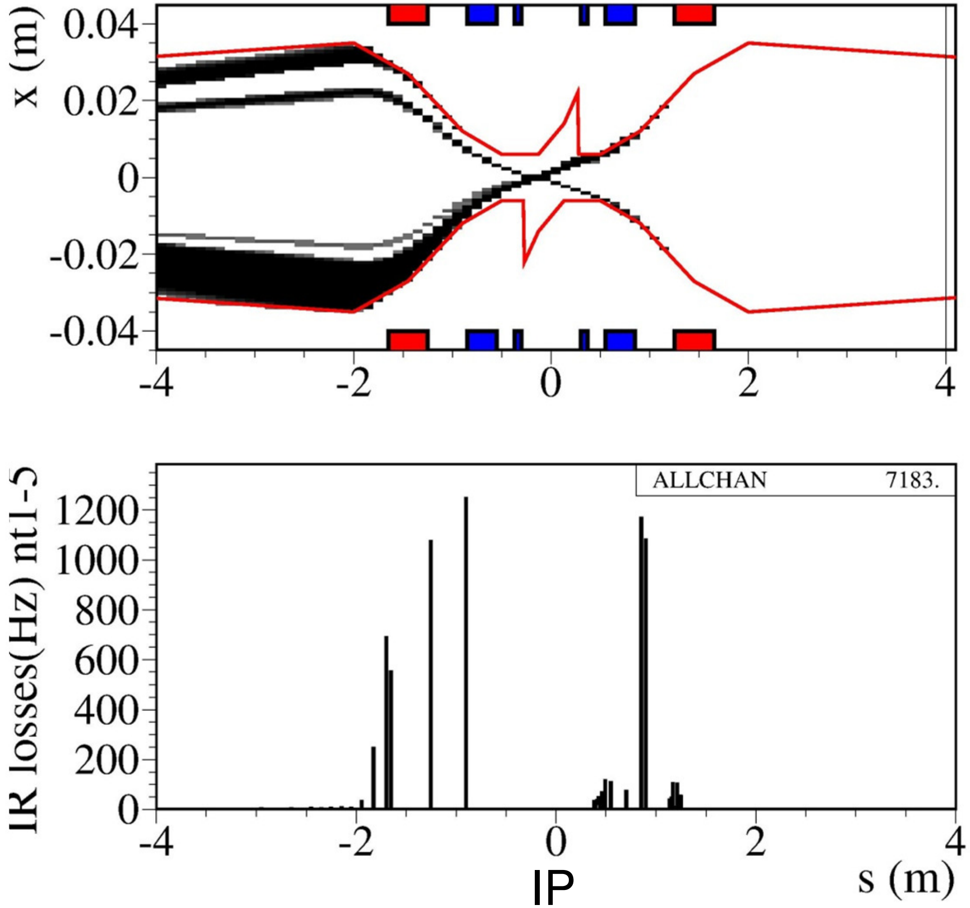
Modif. V12

HER IR losses (|s|< 2 m)

NO collimators = 2.5GHz



with collimators = 7 MHz



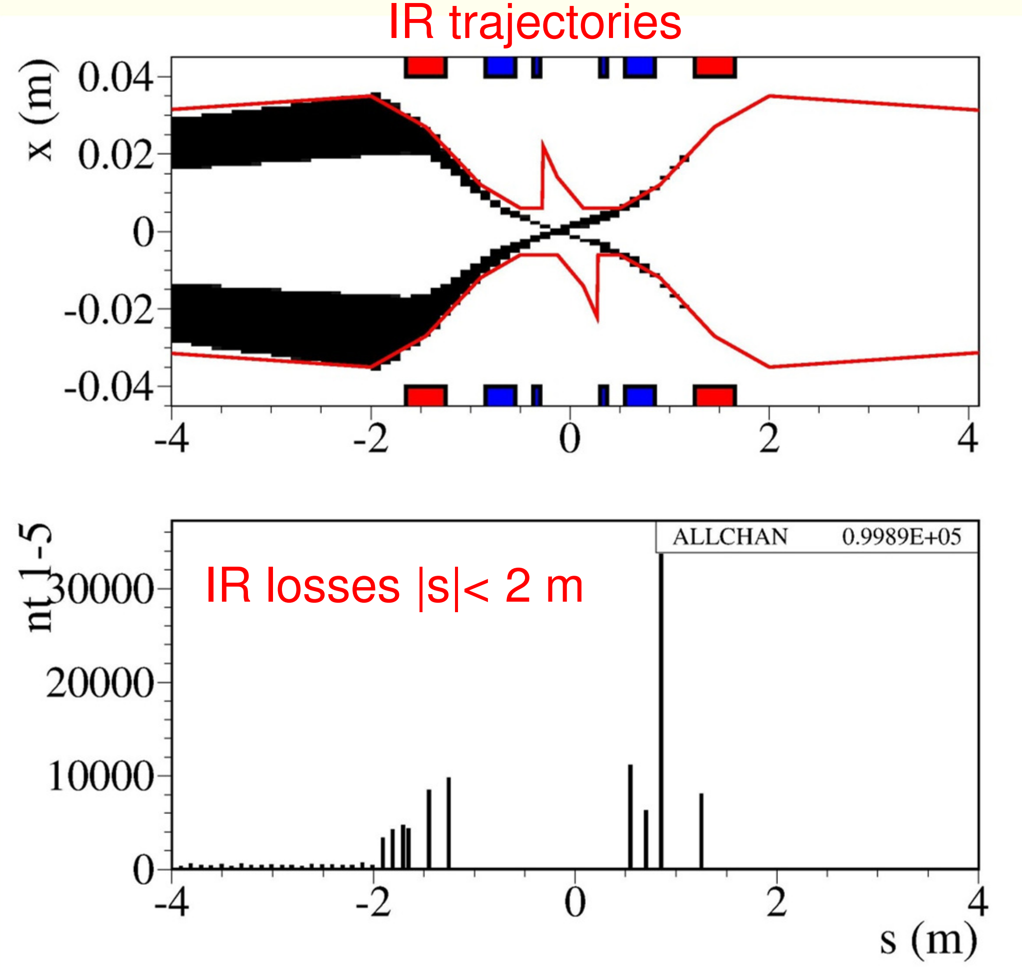
Collimators greatly reduce loss rates

LER final collimators set

I_b =2.5 mA
Bunches 978
ε_x =2.4 nm

Modif. V12

IR trajectories



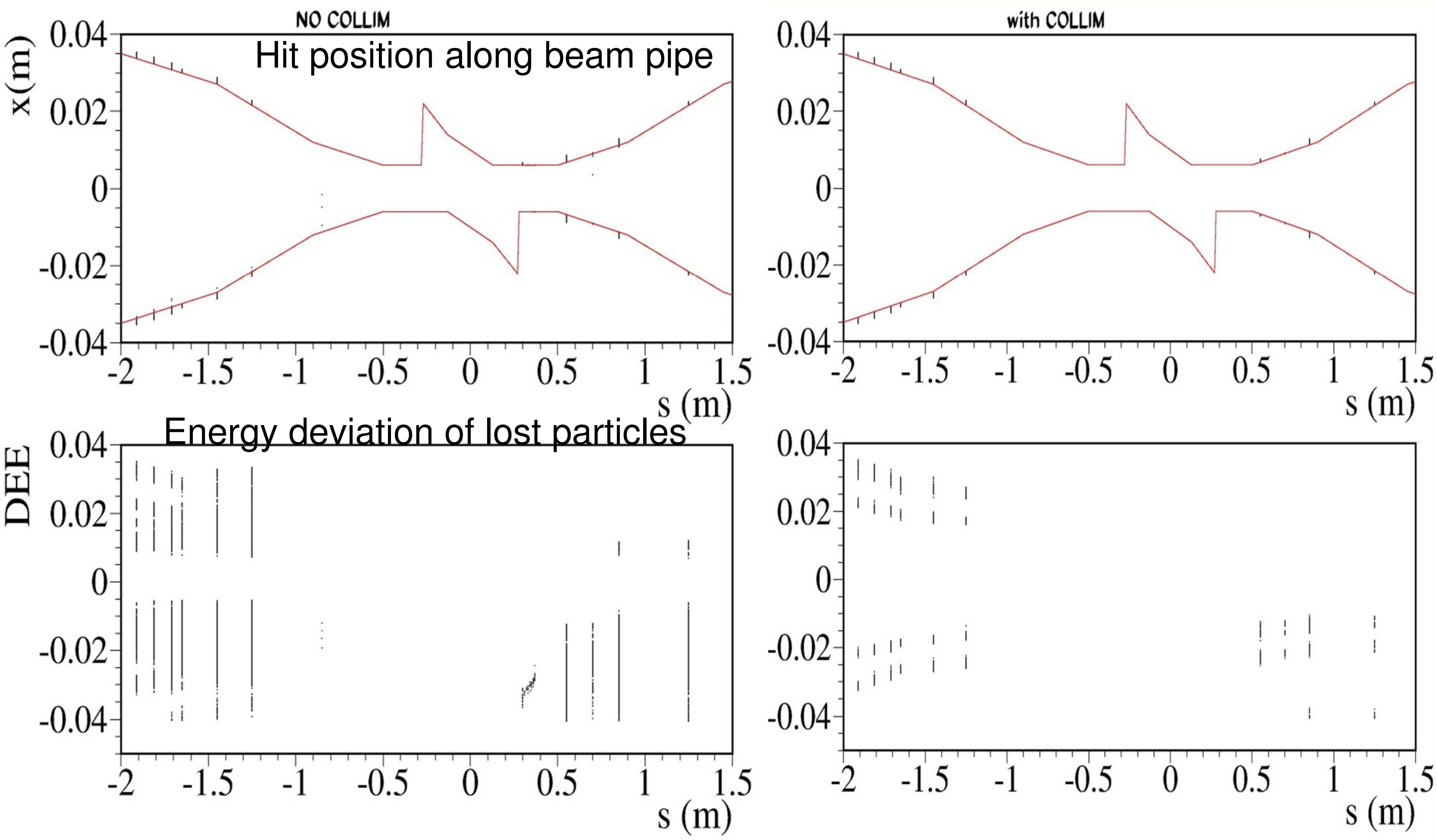
NO collimators
IR losses = 17 GHz

with collimators ≈ 100 MHz
at full current

careful study of secondaries into sub-detectors is on-going to design adequate shieldings

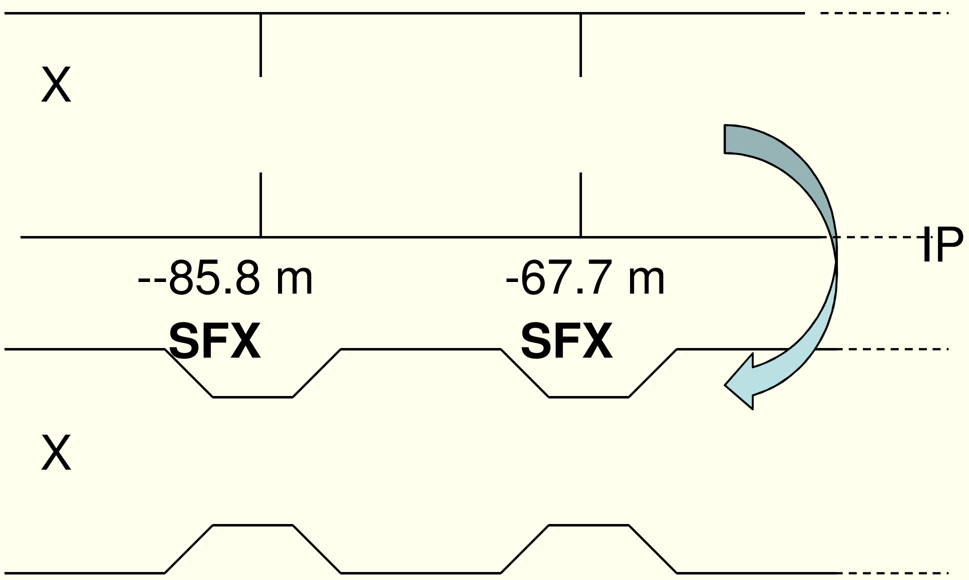
V12Modif.

LER



Proposal: fixed collimators

- The proposed **horizontal collimation system** results **very efficient** from simulations.
- We propose **to model the beam pipe at the longitudinal positions of the primary horizontal collimators** (two hor. Sextupoles) with a horiz. physical aperture corresponding to the one needed for the jaws to efficiently intercept the scattered particles that would be lost at the QF1.



A symmetrically shaped pipe is a better solution from wakefields and HOM point of view instead of collimators

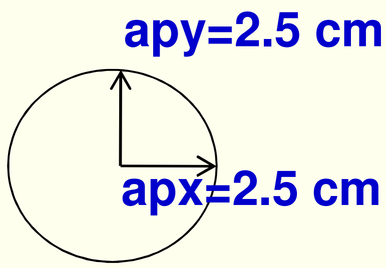
Dedicated discussion planned

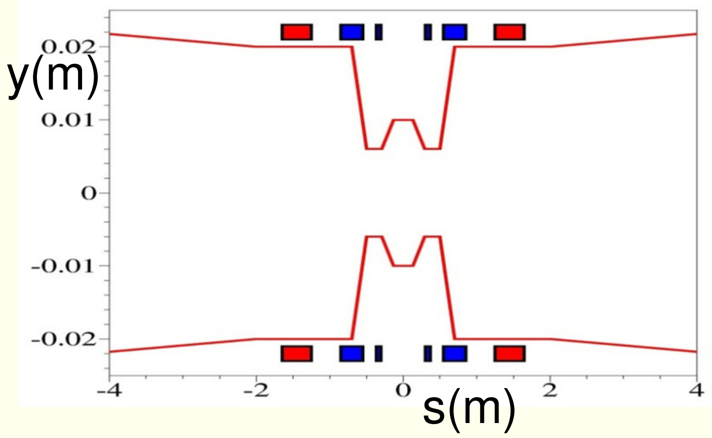
Beam-gas scattering

The same MonteCarlo approach as for Touschek simulation is used by substituting the elastic/ inelastic differential cross-section to the Touschek cross-section

Update on Beam-gas

- Vertical aperture, smaller and more realistic at IR:





- **To do: more realistic pressures along ring- especially at IR**

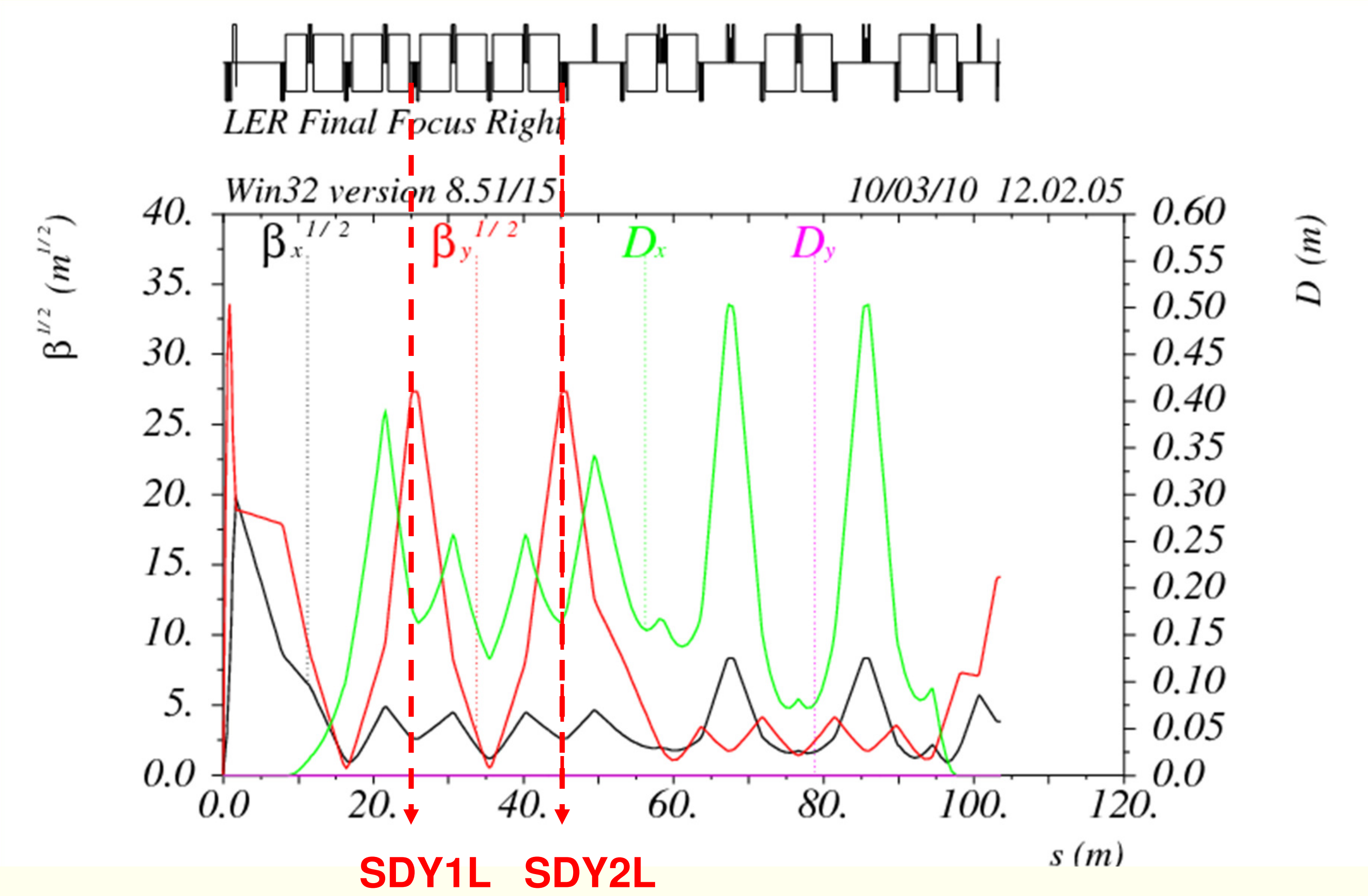
Vertical Collimators upstream the IR

Intercept the scattered particles
in the final focus upstream the IR
that otherwise would be lost at the QD0

Collimator jaw insertion = 0.9* phys. aperture(QD0)$\cdot\sigma_{COL}/\sigma_{QD0}$

With this value IR losses are reduced by a factor
between 700 and 1000

VERTICAL COLLIMATORS



Modif. V12

Beam-gas Coulomb scattering

P = 1 nTorr, Z = 8

LER	**τ (s)**	IR losses
no collimators	2520	25 GHz
with vertical Collimators	2350	**36 MHz**

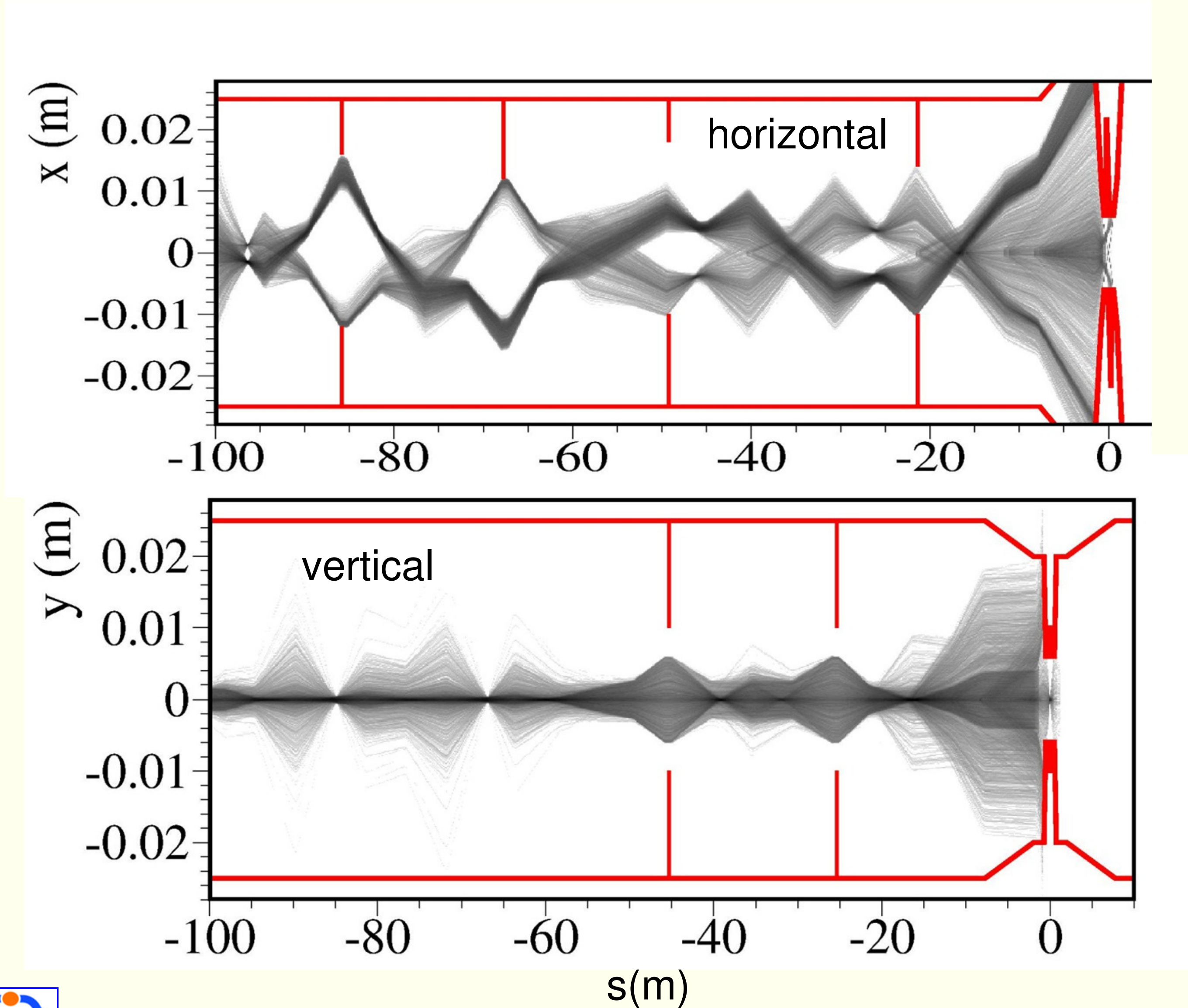
About a factor 700 in IR losses reduction

HER	**τ (s)**	IR losses
no collimators	4590	11 GHz
with vertical Collimators	**3330**	**11 MHz**

About a factor 1000 in IR losses reduction

Coulomb scattering

LER modif. v12

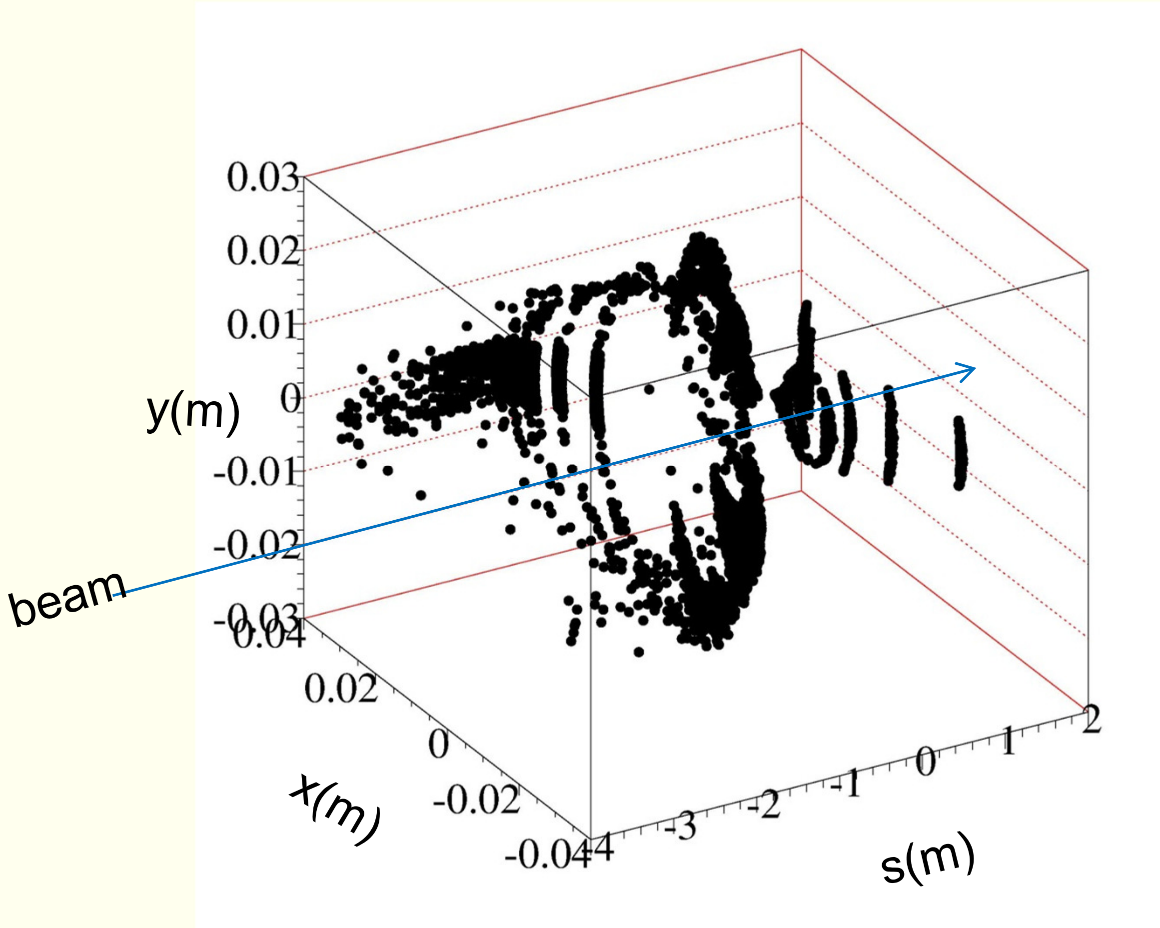


Trajectories of scattered particles eventually lost at IR

Coulomb beam-gas scattering

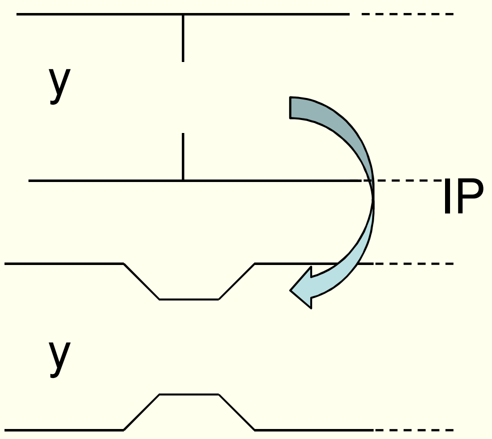
LER Modif.v12

3D plot: scattered particles hitting the pipe



Reshaping of Beam pipe as collimators

A vertical beam pipe at the longitudinal position where the vertical Collimator should be placed (Vertical Sextupoles) could be modeled by the same aperture needed to collimate particles that would be lost at the QD0



A symmetrically shaped pipe is a better solution from wakefields and HOM point of view instead of collimators

Dedicated discussion foreseen

Modif. V12

Conclusions (1): Lifetime summary

	HER	LER
Touschek lifetime	τ_{TOU} (min)	τ_{TOU} (min)
No collimators, nominal ε_x (no IBS)	26.3	7.4
No collimators, ε_x with IBS	26	10.2
With Collimators, ε_x with IBS	22	7.9

Coulomb	76min	39 min
Bremsstrahlung	72 hrs	77 hrs

Modif. V12

Conclusions (2): **IR rates** summary

|s|<2 m

Touschek	HER	LER
No collimators, ε_x with IBS	2.5 GHz	17 GHz
With Collimators, ε_x with IBS	**7 MHz**	**100 MHz**

Coulomb No collimators, ε_x with IBS	11 GHz	25 GHz
Coulomb with collimators, ε_x with IBS	**11MHz**	**36 MHz**
Bremsstrahlung with coll	130KHz	450KHz

V16 lattice - work in progress

- Lifetime is close to the one calculated for the V12 lattice

  energy acceptance large,
  but emittance slightly smaller (1.7nm)

- IR Loss rates are very sensitive to physical aperture,
  M.Sullivan layout will be implemented soon, and
  primaries tracked into sub-detectors

Conclusions

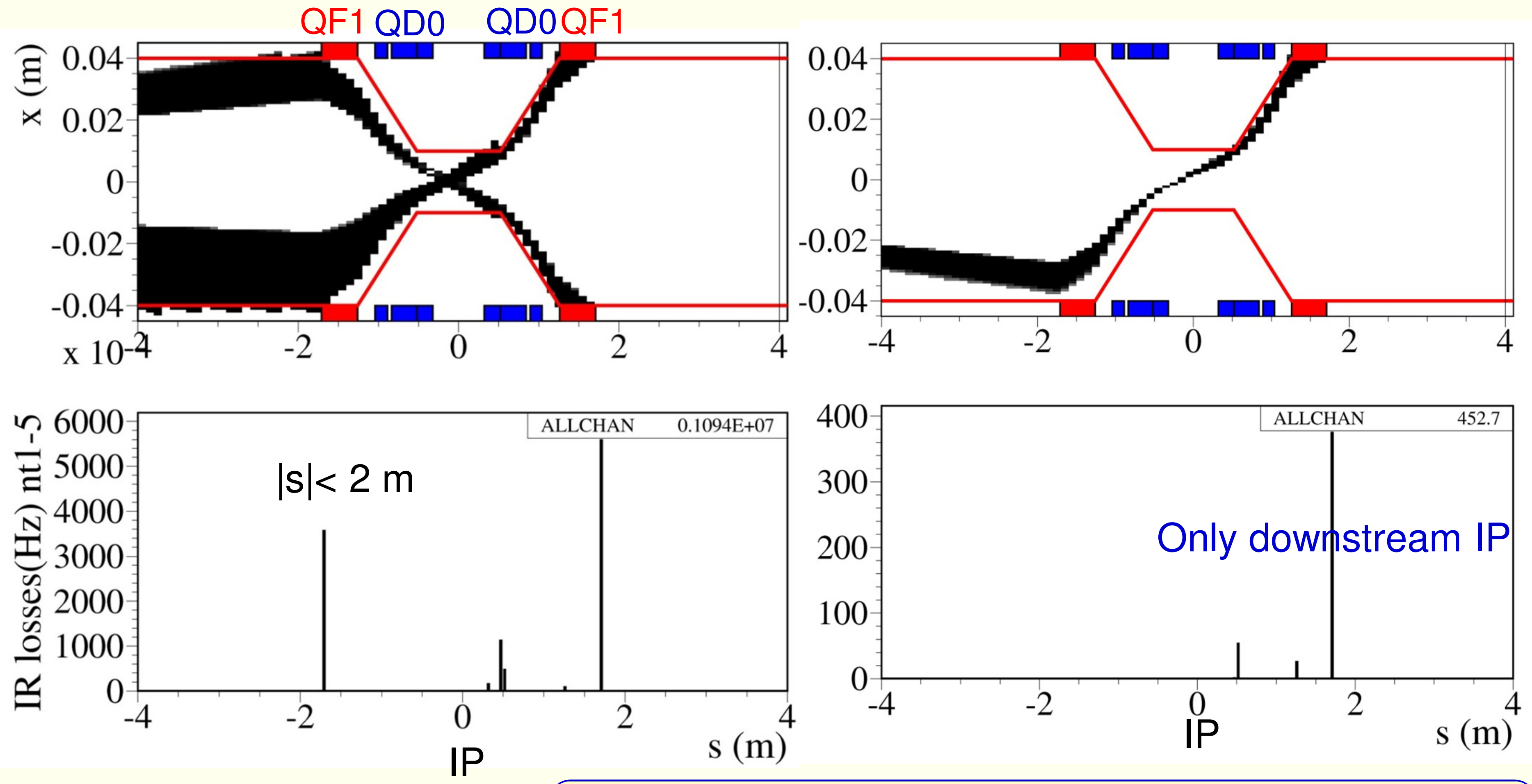
- Monte Carlo for lifetime and backgrounds simulations follows lattice evolution, solid simulation tool (Comparison with DAFNE results done)
- Estimates differ from one optics to another, always consistently
- **to do**: repeat the work for latest lattice (V16)

- Horiz & vert. Collimation system is efficient for all the optics considered, as Final Focus very minor changes
- **To do**: study impedance of realistic collimators
- **To do**: beam-gas consider variable pressure along ring, (much) higher at IR

back-up

v12 HER IR losses (|s|< 2 m)

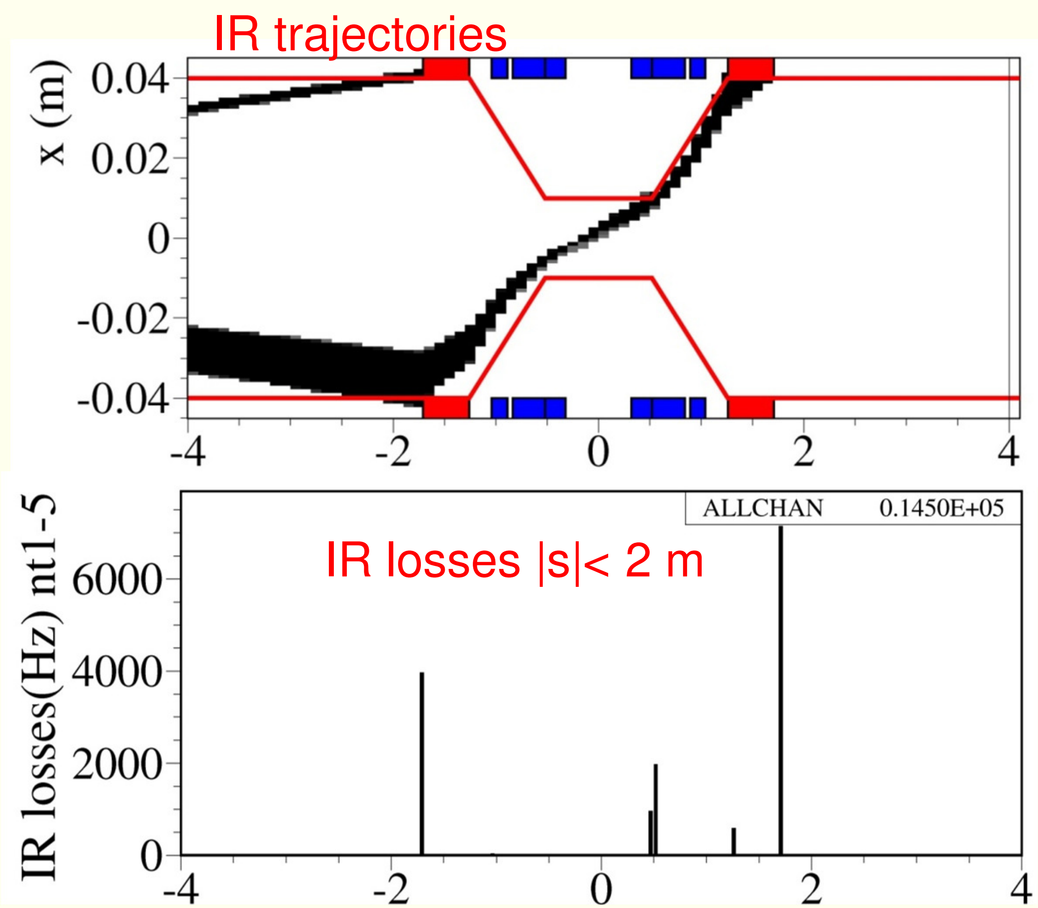
NO collimators = $1.1 \cdot 10^6$ Hz/bunch **with** collimators = $4.5 \cdot 10^2$ Hz/bunch



with collimators=$4.4 \cdot 10^5$ Hz/**beam** at full current
bunches 978

v12

LER final collimators set $\varepsilon_x = 2.4$ nm



NO collimators
IR losses = 6.510^6 Hz/bunch

with collimators
IR losses = 1.4 10^4 Hz/bunch

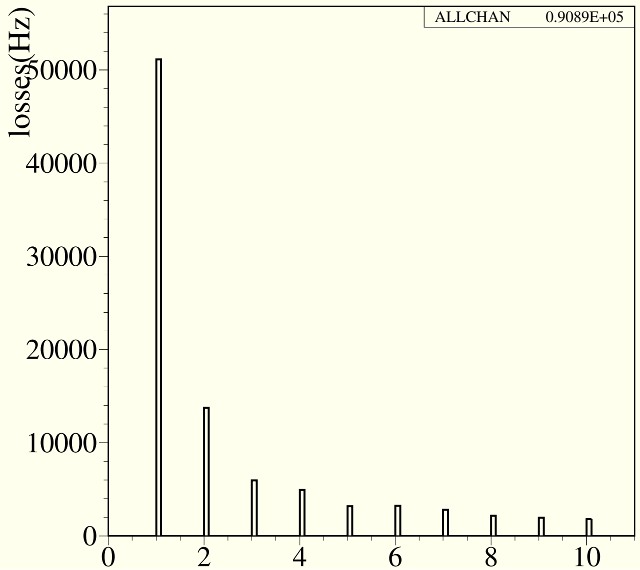
careful study of secondaries into sub-detectors are needed to design adequate shieldings (experience at DAΦNE)

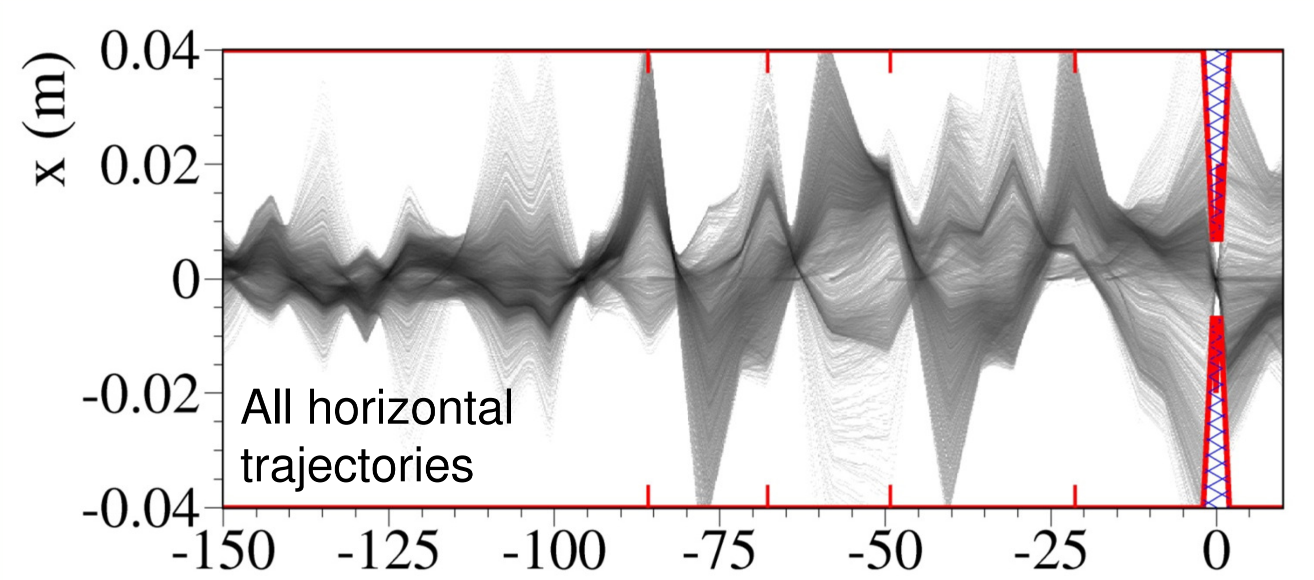
with collimators= 1.37 10^7 Hz/**beam** at full current
bunches 978

M. Boscolo, December 14th 2011

LER Beam-gas Bremsstrahlung

V12 lattice

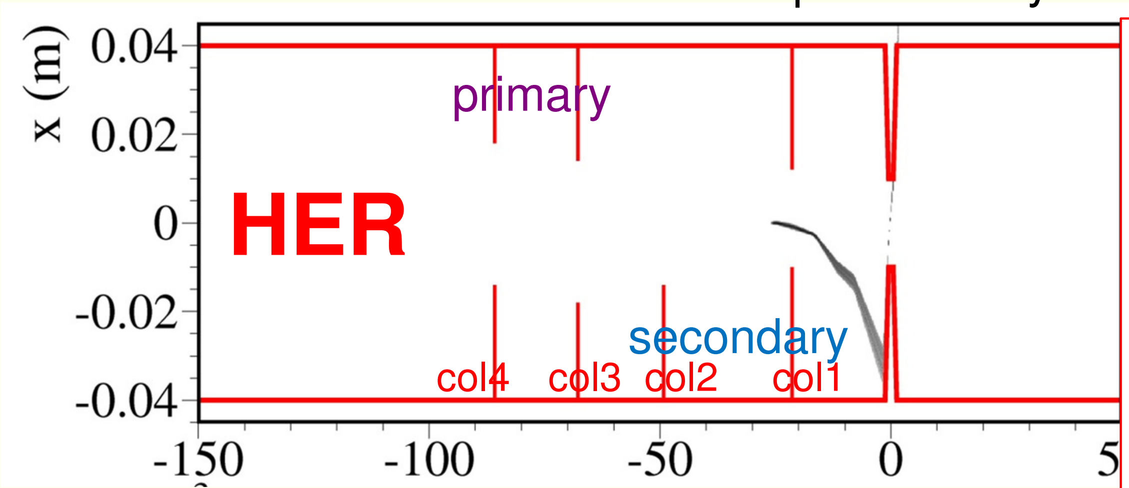




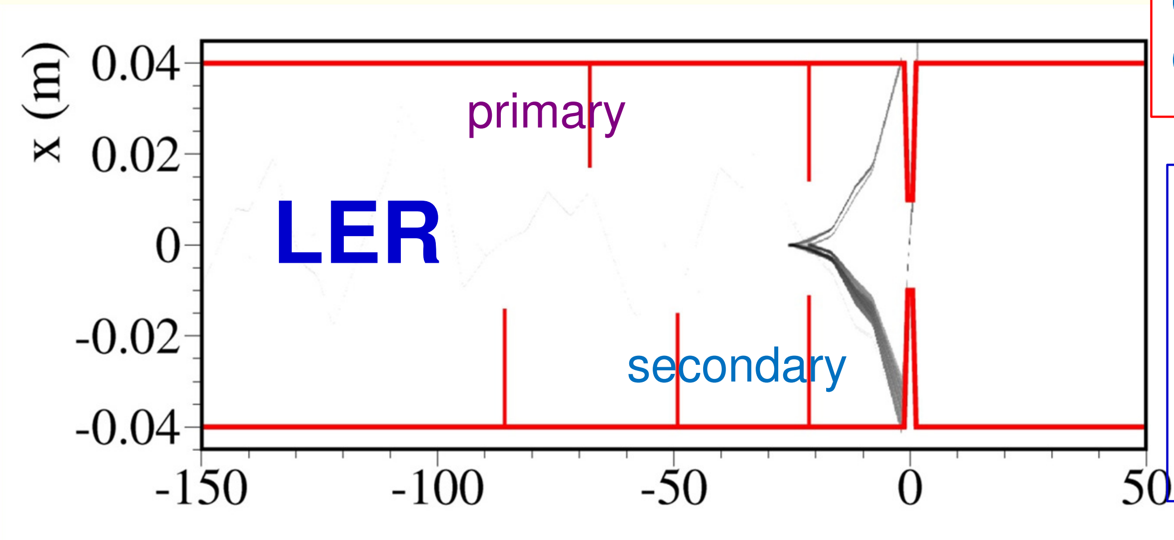
v12

Collimators Final set from the simulation

found by minimizing IR rates and maximizing lifetime
real set will be found experimentally



SET (σ_x units):
Col1= -26 /+31 σx
Col2= -26 σx
Col3= -36/ +28 σx
Col4= -28/ 36 σx
SET (cm):
Col1= -1.2 / +1.2
Col2= -1.
Col3= -1.8 / +1.4
Col4= -1.4 / 1.8



SET (σ_x units):
Col1= -28 /+35 σx
Col2= -35 σx
Col3= +29 σx
Col4= -25 σx

CDR and CDR2

CDR

Table 3-17. *Touschek beam lifetime summary.*

Parameter set	Luminosity ($m^{-2}s^{-1}$)	Lifetime HEB (min)	Lifetime LEB (min)
Nominal	1.0×10^{36}	38	5.5
Upgrade	2.44×10^{36}	19	3

Table 3-16. *Nominal* Super*B* *beam parameters.*

	HER	LER
Beam Energy (GeV)	7	4
Bunch length (mm)	6	6
Energy spread (%)	0.1	0.1
Horiz. emittance (nm)	1.6	1.6
Vertic. emittance (pm)	4	4
Energy acceptance (% $\Delta p/p$)	1	1
β_x avg. (m)	10	10
β_y avg. (m)	22	22
ppb	3.52×10^{10}	6.16×10^{10}

CDR2

Touschek lifetime [min]	HER	LER
No collimators, ε_x including IBS	40.0	7.8
No collimators, nominal ε_x (no IBS)	39.8	5.9
Optimal set of Collimators, ε_x including IBS	33.2	6.6

V12 parameters	HER	LER
Beam Energy (GeV)	6.7	4.18
Bunch length (mm)	5	5
Nominal horizontal emittance (nm)	1.97	1.80
Horiz. emittance (nm) including IBS	2.00	2.46
Coupling (%)	0.25	0.25
Particles/bunch	5.08×10^{10}	6.56×10^{10}

Program Flow Touschek simulation

Optics check

(nonlinearities included)

Beam parameters calculation
(betatron tunes, emittance, synchrotron integrals, natural energy spread, bunch dimensions, optical functions and Twiss parameters all along the ring)

Calculation of Touschek energy spectra all along the ring averaging Tousc. probability density function over 3 magnetic elements

Tracking of Touschek particles:
Start with transverse gaussian distribution and proper energy spectra every 3 elements: track over many turns or until they are lost

- Estimation of IR and total Touschek particle losses
  (rates and longitudinal position)
- Estimation of Touschek lifetime