Simulation on beam loss and lifetime from Radiative Bhabha process

M. Boscolo

4th SuperB Collaboration Meeting
La Biodola, Isola d'Elba
June 2nd 2012

Introduction

- **Touschek** & **Beam-gas extensively studied**
  - Collimation system
  - Simulation results for LER & HER

NEW!

- **Multi-turn Simulation due to Radiative Bhabha process with specific lattice (with nonlinear terms)**
  - same lattice as for Touschek and beam-gas: V12 +Mike's FF
  - same collimators configuration as for Touschek and beam-gas

→ Evaluation of beam loss and lifetime

Up to now: approach used for Radiative Bhabha process studies

- Up to now radiative Bhabha **lifetime** estimated assuming 1% energy acceptance:

$$\dot{N} = \sigma(dE/E > 1\%) \cdot L$$ [CDR2, E. Paoloni]

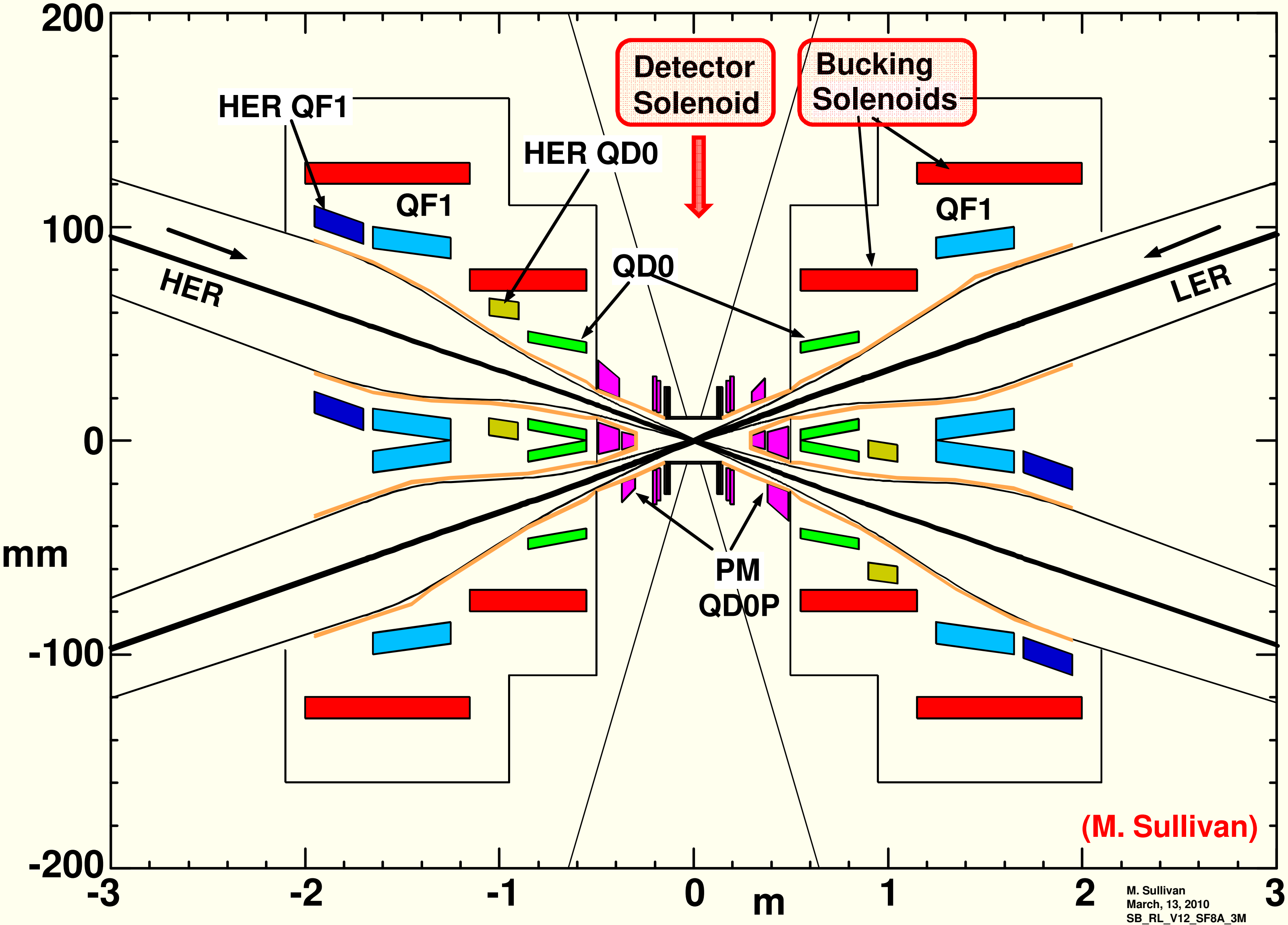
- Beam **Losses** carefully studied with Geant4, after generating off-energy particles using BBBrem

Monte Carlo Simulation approach

- This study: track Bhabha final states particles for many machine turns, for a chosen lattice and nonlinear terms configuration, allowing to evaluate:
  - the loss probability for these particles as a function of their dE/E
  - lifetime
  - Losses

- Same technique as for beam-gas and Touschek

IP region
Air core "Italian" QD0, QF1



Parameters used in the IR designs

(Mike Sullivan, Dec. 11)

Parameter	HER	LER	
Energy (GeV)	6.70	4.18	
Current (A)	1.89	2.45	
Beta X* (mm)	26	32	(26)
Beta Y* (mm)	0.253	0.205	(0.274)
Emittance X (nm-rad)	2.00	2.46	
Emittance Y (pm-rad)	5.0	6.15	
Sigma X (μm)	7.21	8.87	
Sigma Y (nm)	36	36	
Crossing angle (mrad)	+/- 30		

Studies done for:

- LER
  - No collimators
  - With collimators
- HER
  - No collimators
  - With collimators

Same conditions as for Touschek & beam-gas
20 machine turns

Lifetime evaluation

$$\frac{1}{\tau_{rad}} = \frac{\dot{N}(Hz)}{N}$$

rate of losses due to radiative Bhabha for N(particles/bunch)

τ_{rad} is the calculated radiative Bhabha lifetime

- CDR2

Table 9.4: Radiative Bhabha beam lifetimes for several SuperB options.

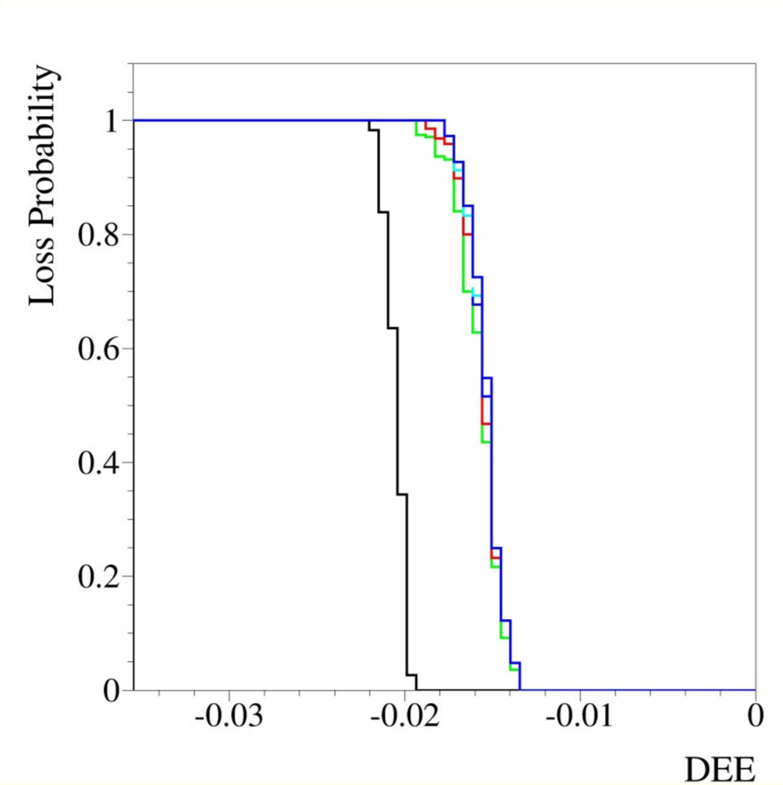
	Base Line		Low Emittance		High Current	
	HER	LER	HER	LER	HER	LER
τ (min)	4.87	6.29	3.76	4.85	7.96	10.3

- Monte Carlo:

HER τ_{rad} = 4.7 min

LER τ_{rad} = 7.0 min

LER Multi-turn Energy acceptance



20 machine turns

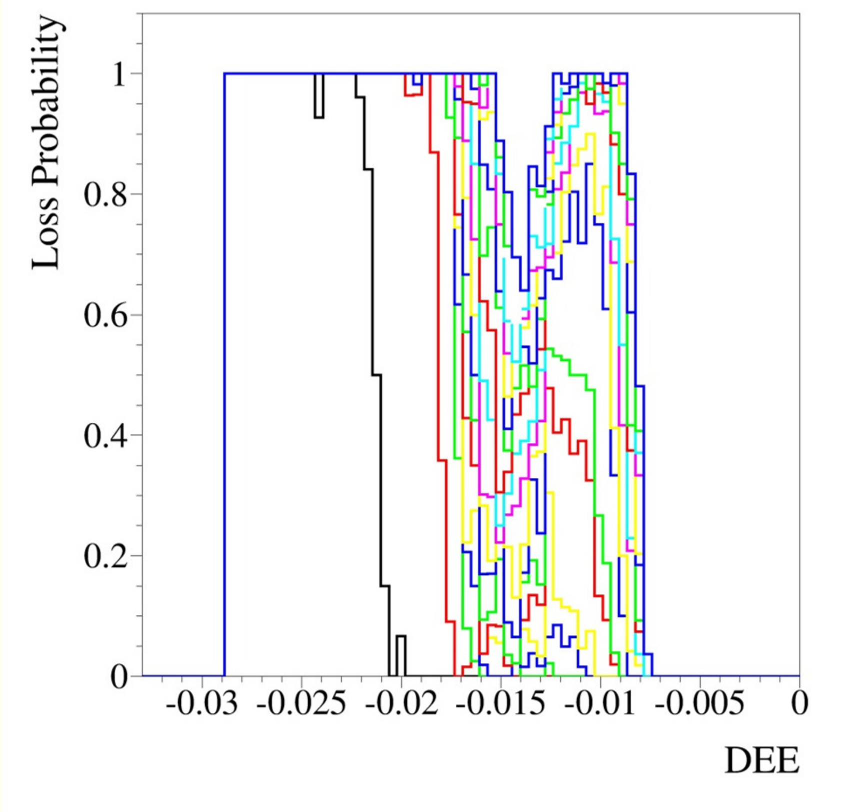
Energy acceptance ≈ 1.5%

rad Bhabha lifetime evaluated for the LER is about 10% larger than what comes out when assuming dE/E>1%, Obtaining

τ(rad) =7 min

- Up to now [CDR2] rad Bhabha lifetime estimated assuming energy acceptance of 1% and τ(rad) =6.3 min
- My result is consistent: if we assume dE/E=1.5%, τ(rad) =7 min

HER Multi-turn Energy acceptance



20 machine turns

Energy acceptance < 1.%

rad Bhabha lifetime evaluated for the LER is slightly smaller wrt that obtained with the dE/E>1% assumption

τ(rad) =4.7 min

- Up to now [CDR2] rad Bhabha lifetime estimated assuming energy acceptance of 1% and τ(rad) =4.87 min
- My result is consistent: if we assume dE/E=0.8%, τ(rad) =4.7 min

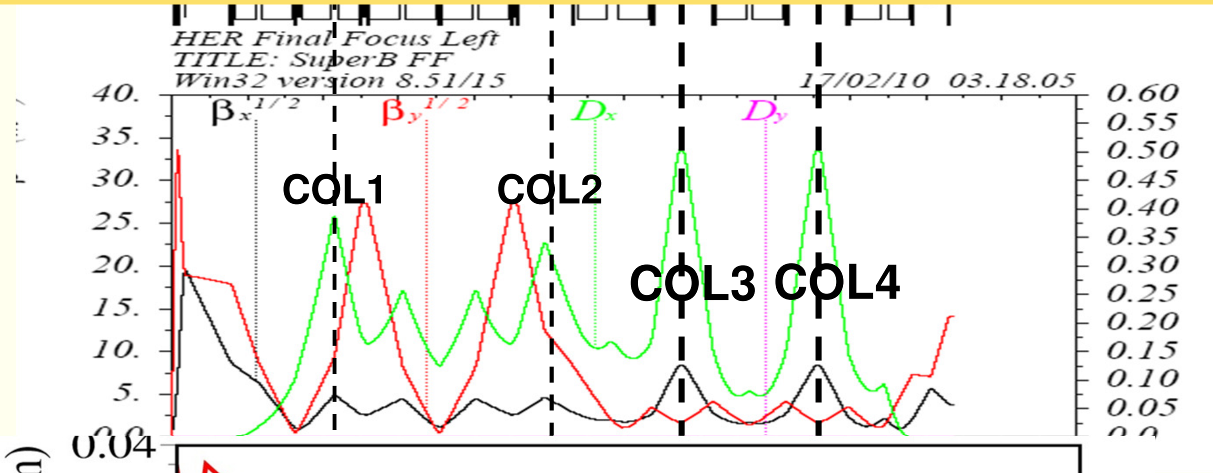
Backgrounds from rad Bhabha process

- 1 turn losses already studied (BBBrem+Geant4)
- Particles with dE/E>rf acceptance do not reach the IP again
  - Taken into account for lifetime evaluation
  - Not considered for the backgrounds studies
- New: multi-turn losses for 0<|dE/E|<rf acceptance

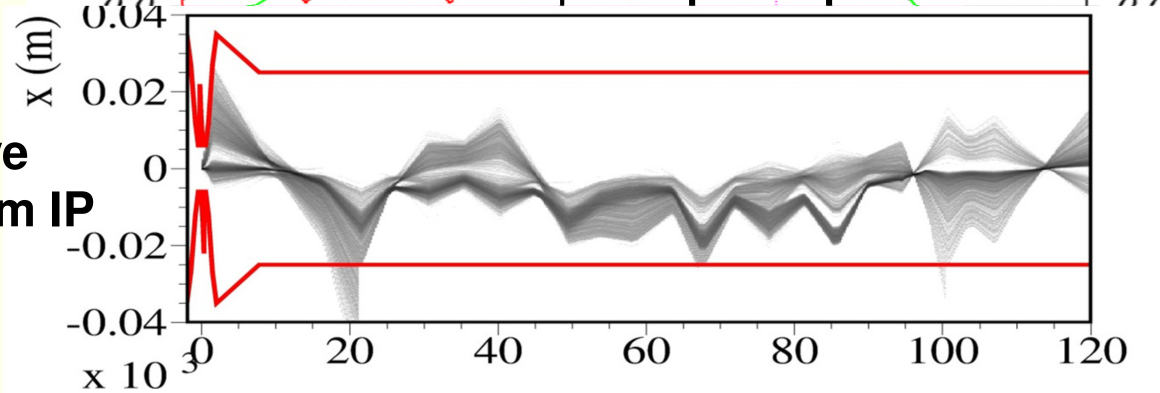
Trajectories Bhabha final states particles

LER
No collimators

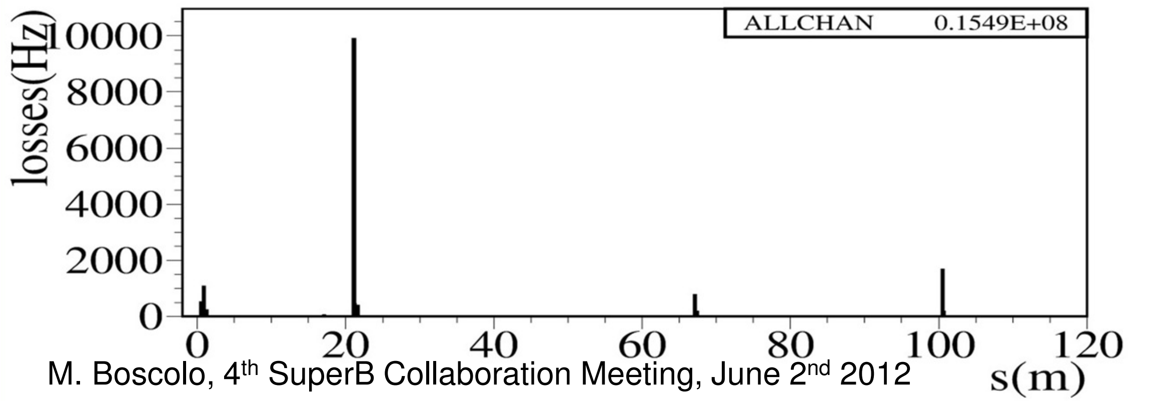
Optical functions in the Final Focus



Trajectories final state radiative Bhabha particles from IP

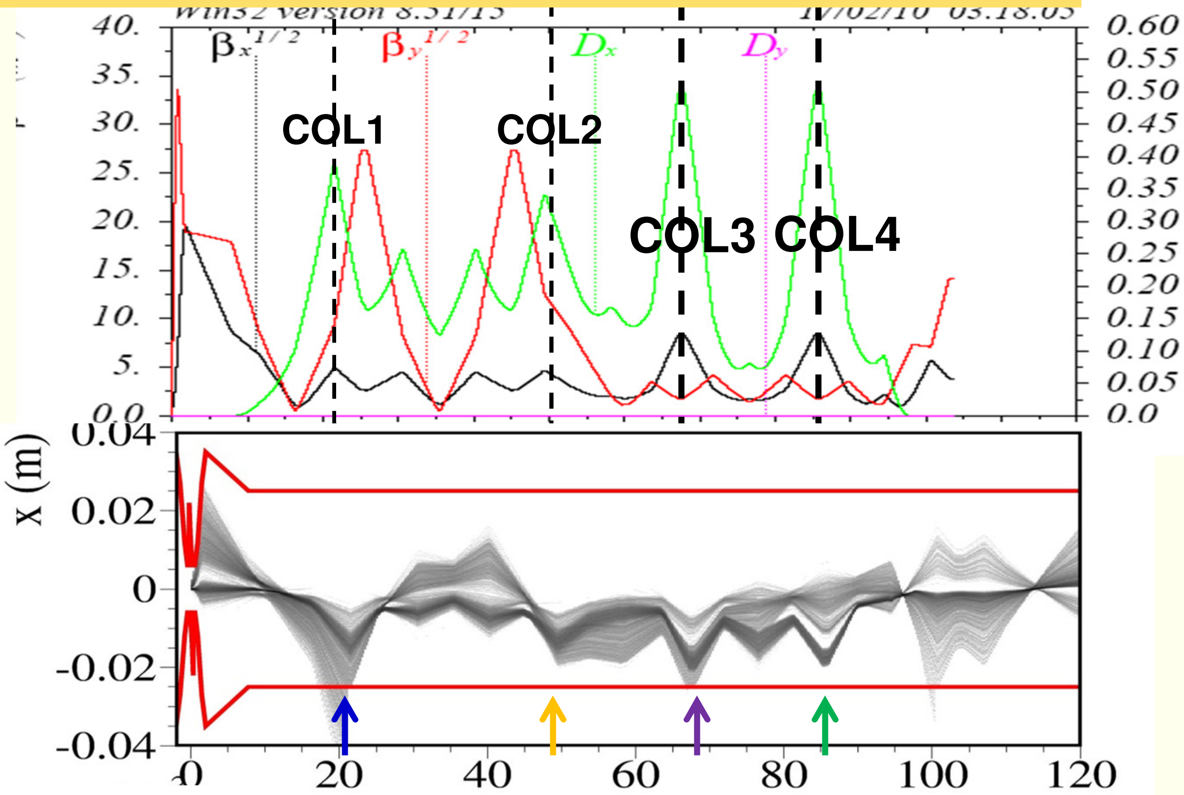


Loss points in the Final Focus



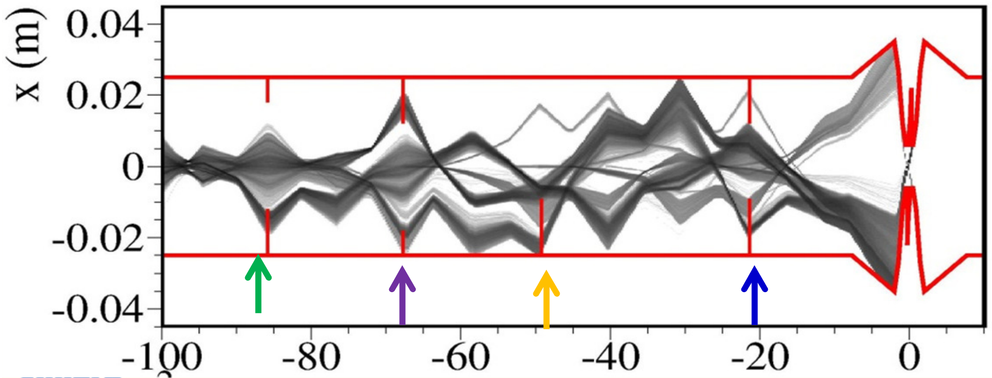
Trajectories Bhabha final states particles

LER
No collimators



Trajectories final state radiative Bhabha particles from IP

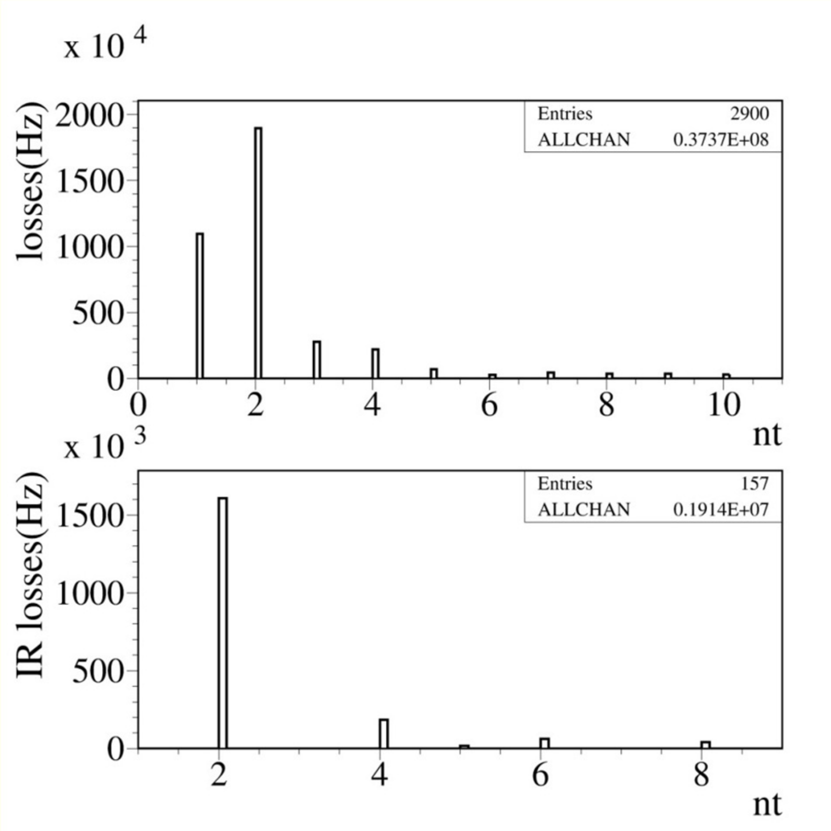
Same phase advance as Touschek particles!



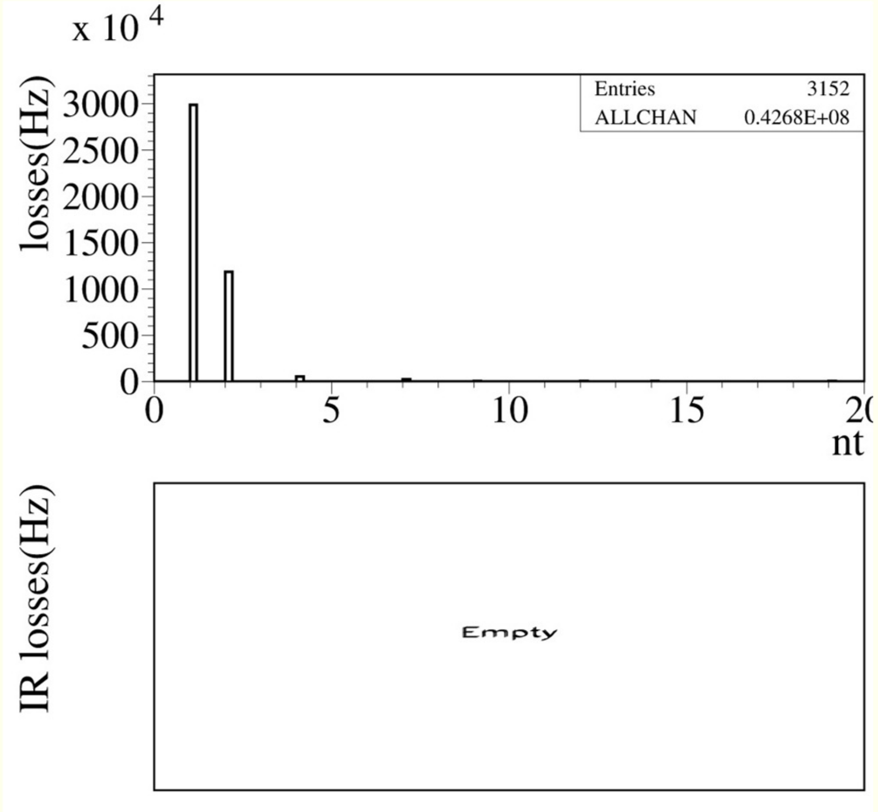
Trajectories of particles after Touschek scattering upstream IP

LER Losses from Rad Bhabha process vs machine turns

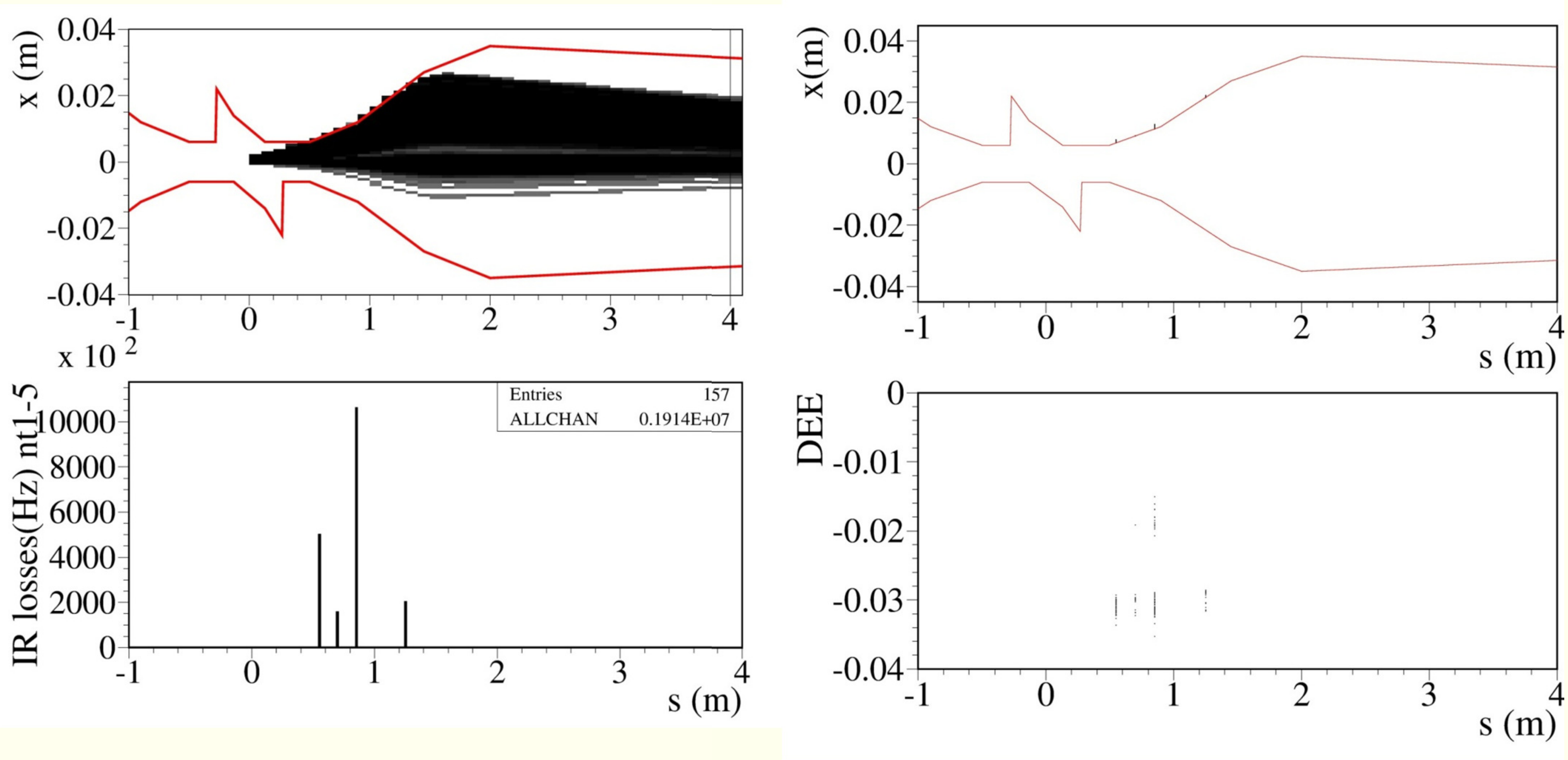
LER no collimators



LER with collimators
(same set of Touschek &beam-gas)



LER Loss rate at IP for dE/E<4%

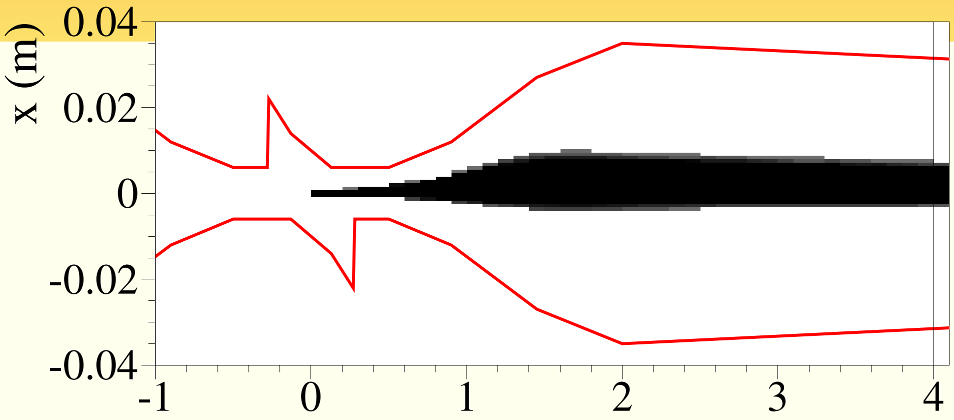


With collimators

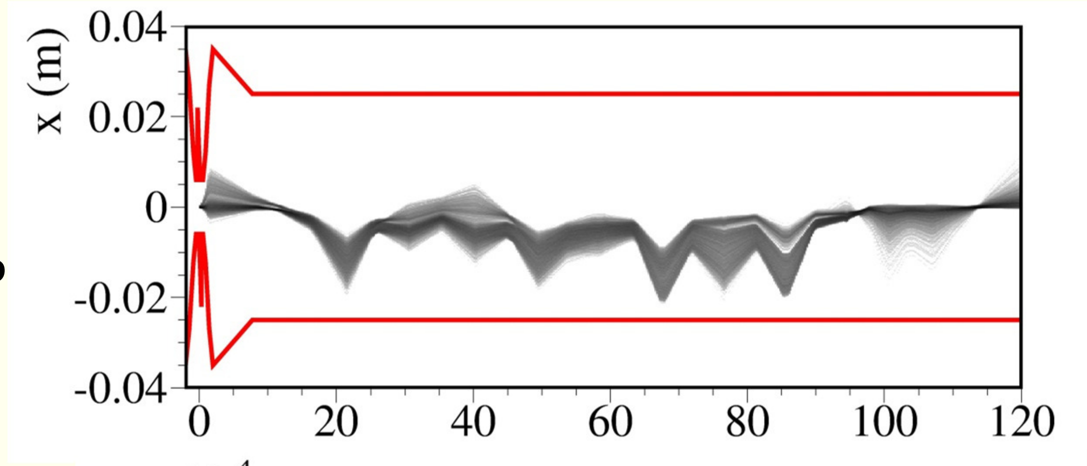
- Same set used for Touschek and beam-gas
- Radiative Bhabha particles are stopped by collimators, as they have the same horizontal phase advance as Touschek particles
- Collimators do not reduce lifetime -> good news!

LER with collimators

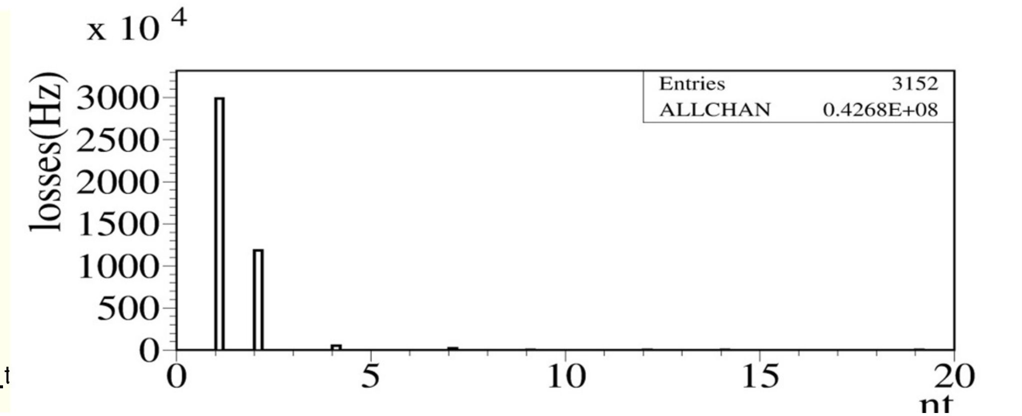
IR: Trajectories final state radiative Bhabha particles from IP



Trajectories in the Final Focus of final state radiative Bhabha particles from IP

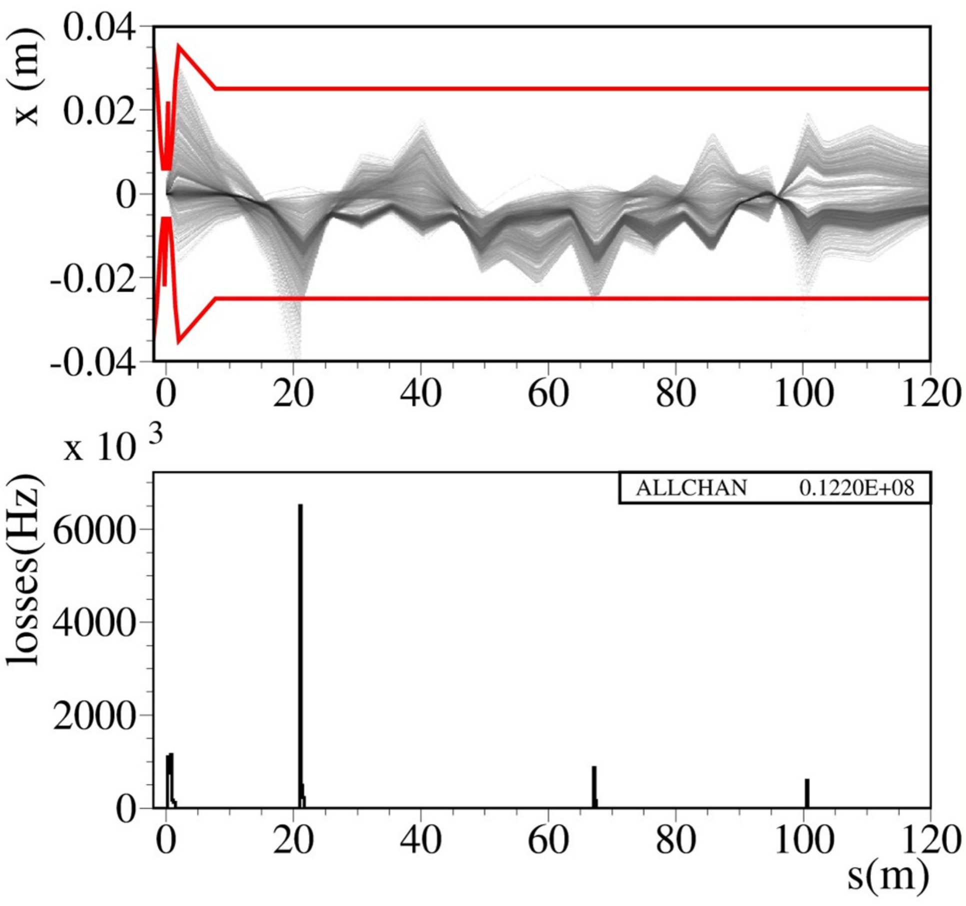


Total losses vs Machine turns

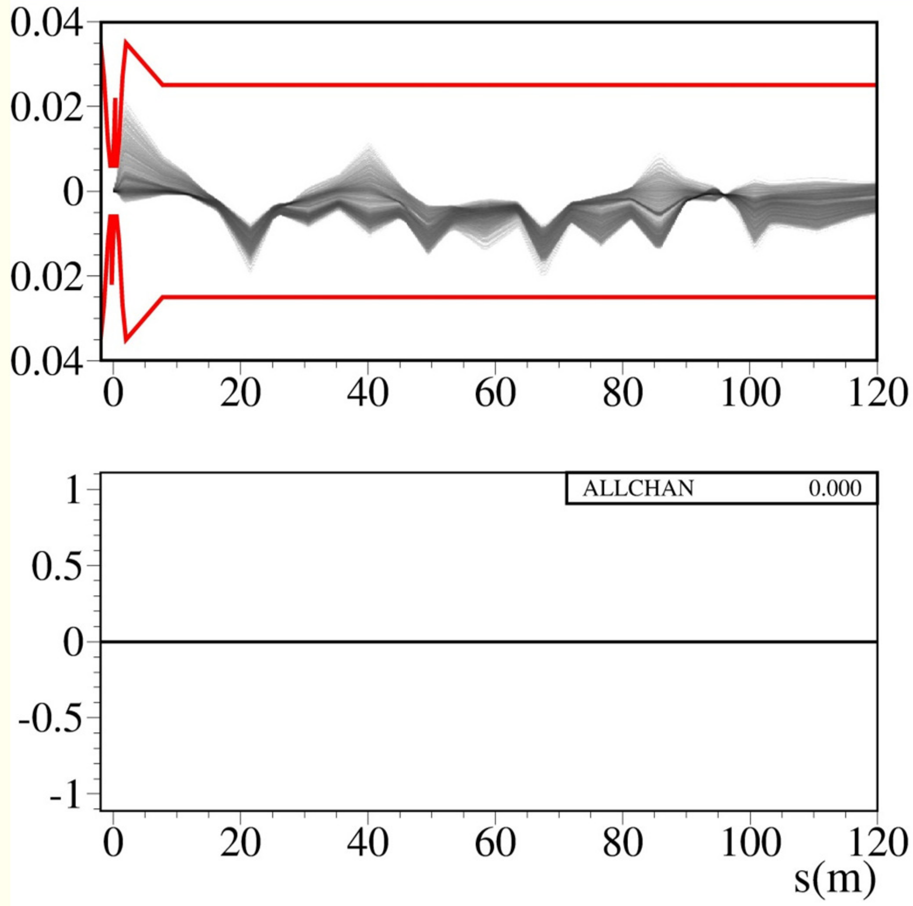


HER losses from rad Bhabha process

HER no collimators

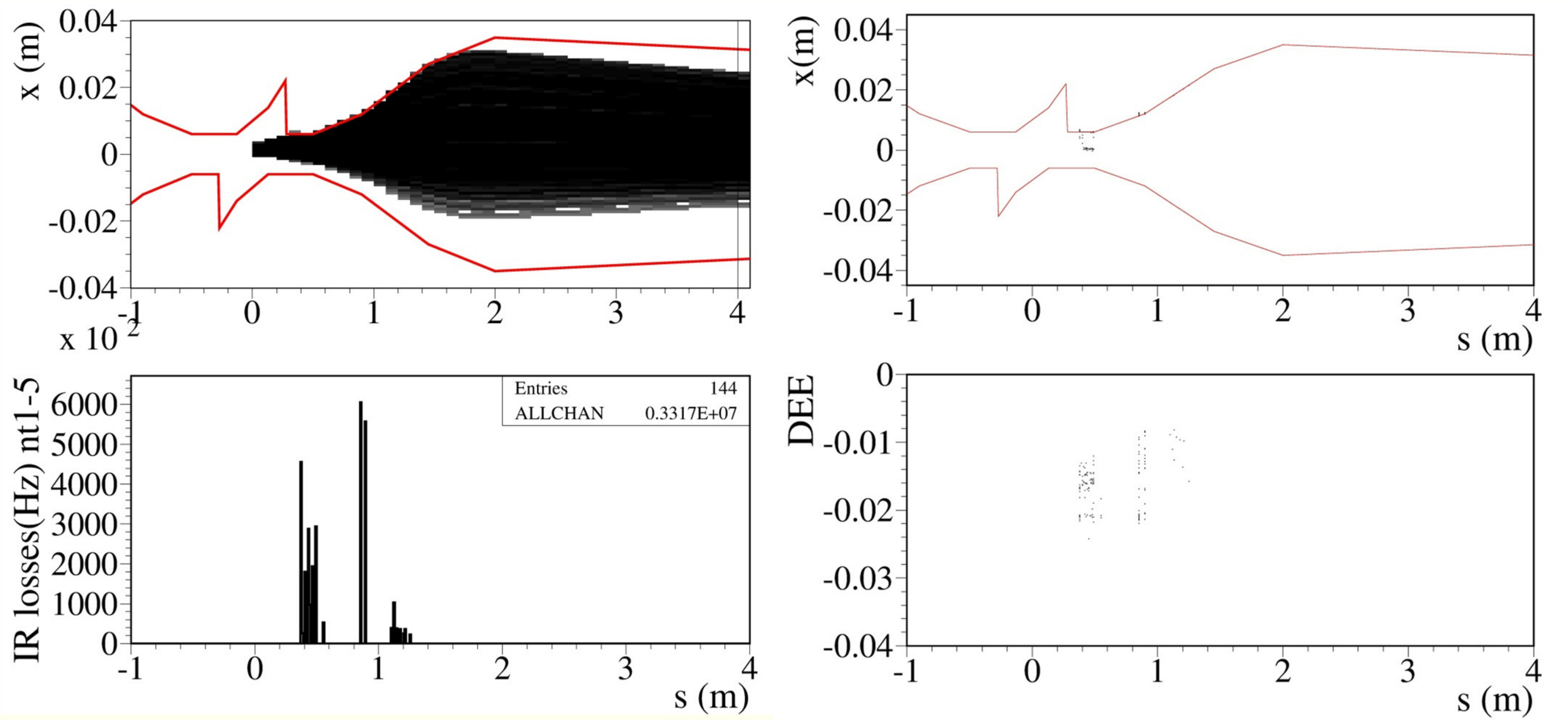


HER with collimators
(same set of Touschek &beam-gas)



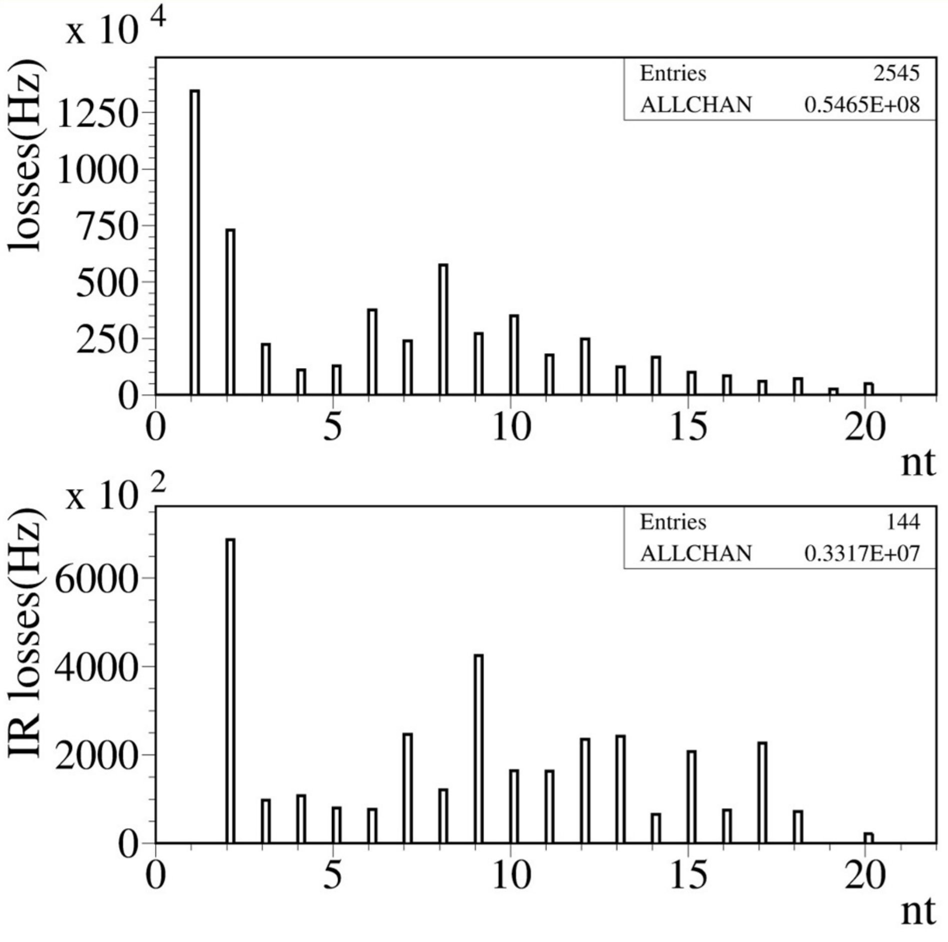
HER losses from rad Bhabha process

HER no collimators

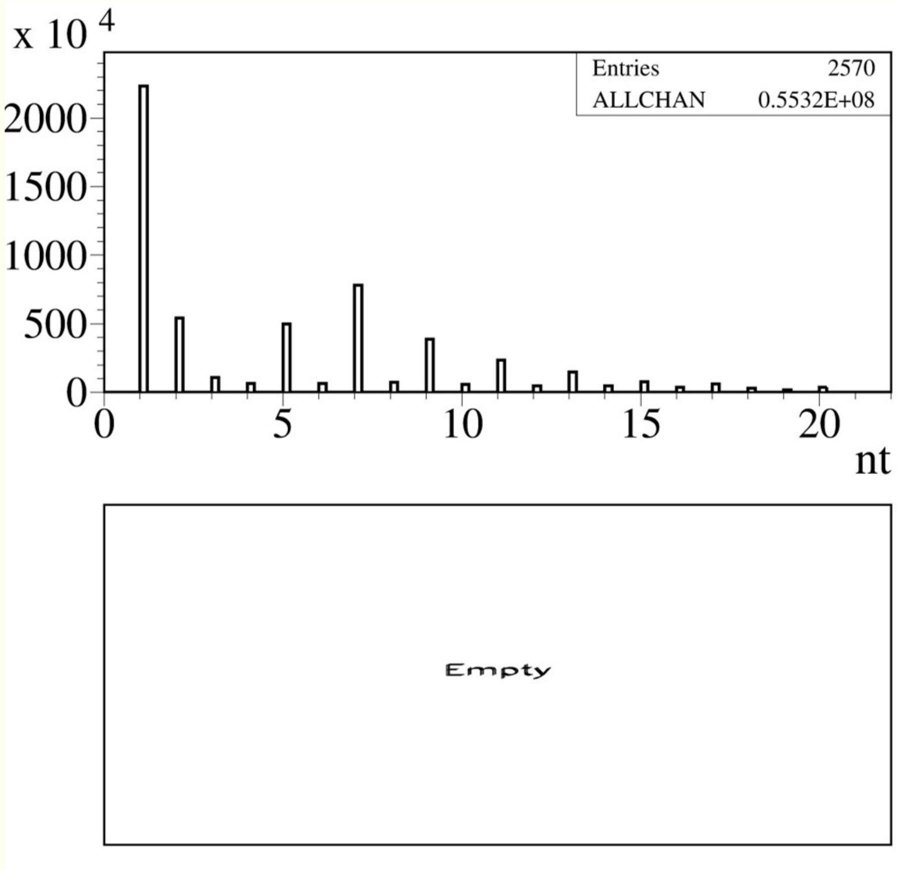


HER losses from rad Bhabha process

HER no collimators



HER no collimators



Lifetime summary

lifetime	HER τ(min)	LER τ(min)
Radiative Bhabha lifetime	4.7	7
Touschek No collimators, ε_x with IBS	26	10.2
Touschek With Collimators, ε_x with IBS	22	7

Coulomb (for LER updated collim set wrt March12)	50 min	23.7 min
Bremsstrahlung	72 hrs	77 hrs

IR rates summary

|s|<2 m

Touschek	HER	LER
No collimators, ε_x with IBS	2.4 GHz	17 GHz
With Collimators, ε_x with IBS	**6.8 MHz**	**72 MHz**

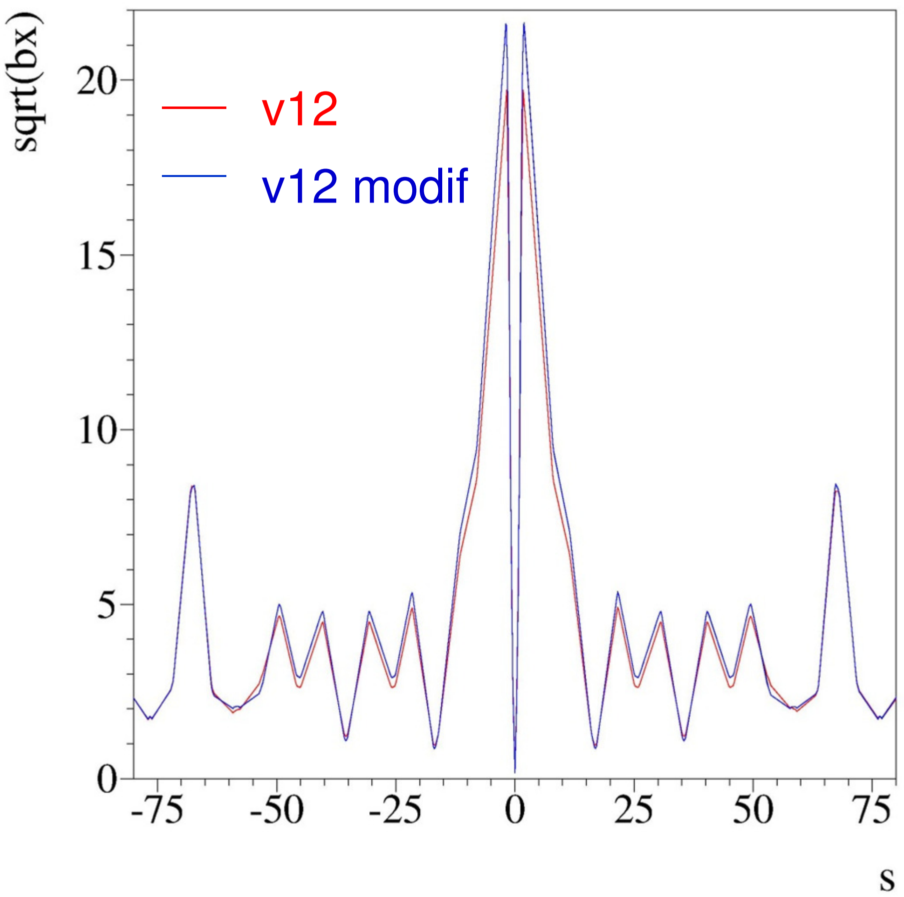
Coulomb No collimators, ε_x with IBS	10.5 GHz	25 GHz
Coulomb with collimators, ε_x with IBS	**3.7MHz**	**36 MHz**
Coulomb with updated collim wrt March12	**3.7MHz**	**20 MHz**
Bremsstrahlung with coll	130KHz	450KHz

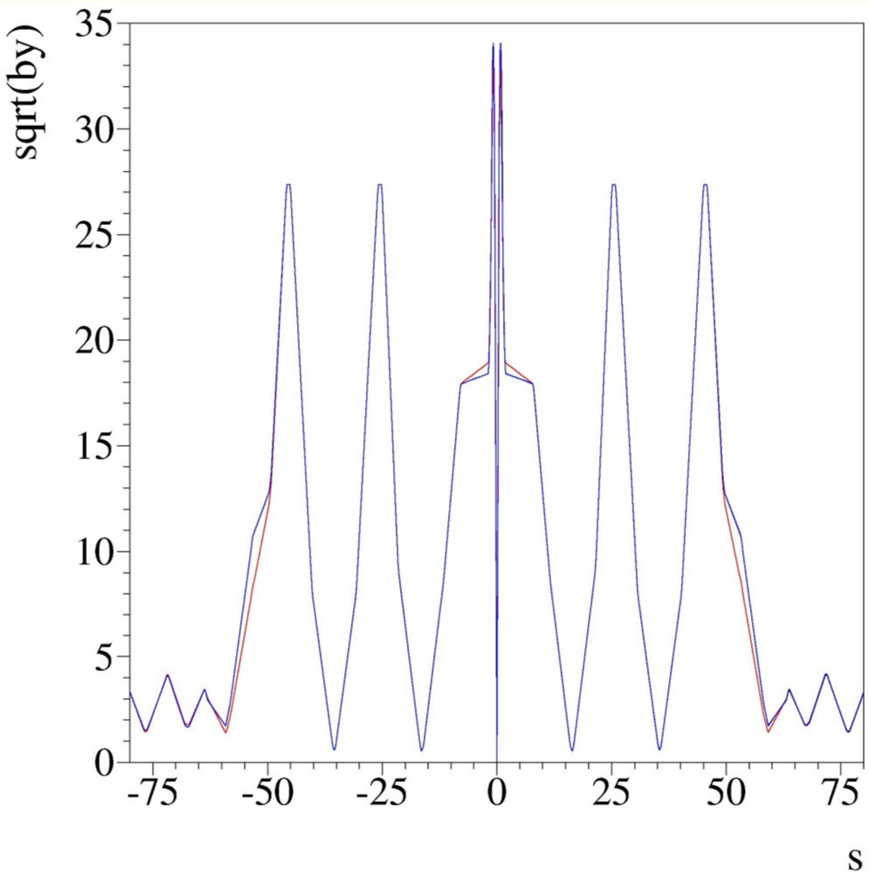
Conclusions

- Radiative Bhabha background source studied with the same approach used for Touschek and beam-gas
- Consistent results with the CDR2 lifetime evaluation found
  - Slight difference due to energy acceptance, (assumed 1% for CDR)
- Multi-turn losses evaluated for the first time
  - Present collimators very effective (rad Bhabha & Touschek have same phases)
- Next:
  - Track primaries into sub-detectors
  - Study elastic Bhabha

Back-up

HER Optics: zoom of Final Focus

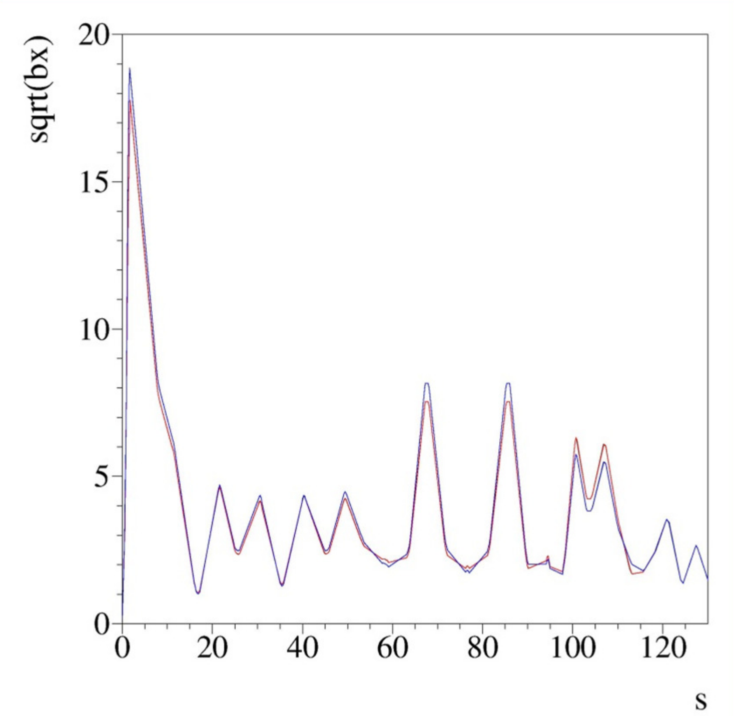


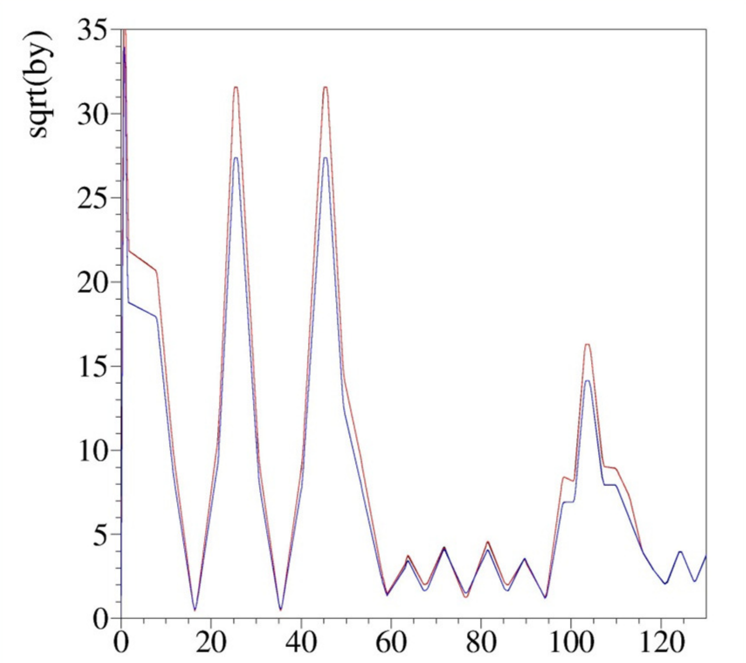


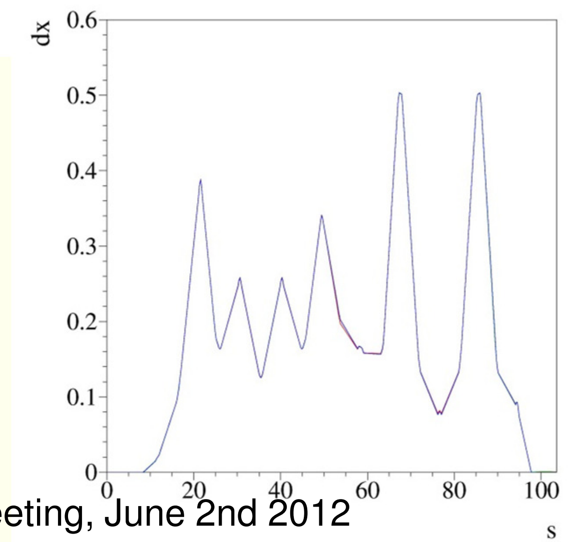
beta_x* = 2.6cm
beta_y* = 0.27mm

beta_x* = 2.6cm
beta_y* = 0.27mm

LER Optics: Final Focus







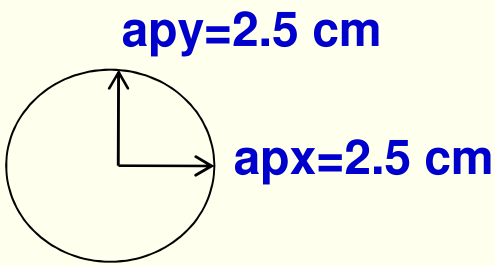
—— v12 beta_x* = 3.2cm
beta_y* = 0.206mm

Nominal values

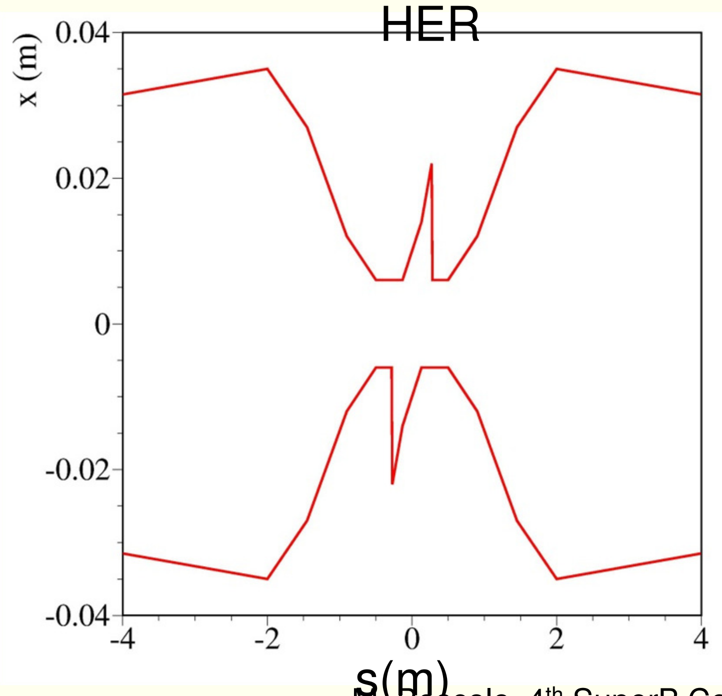
—— v12 modif beta_x* = 2.6cm
beta_y* = 0.274mm

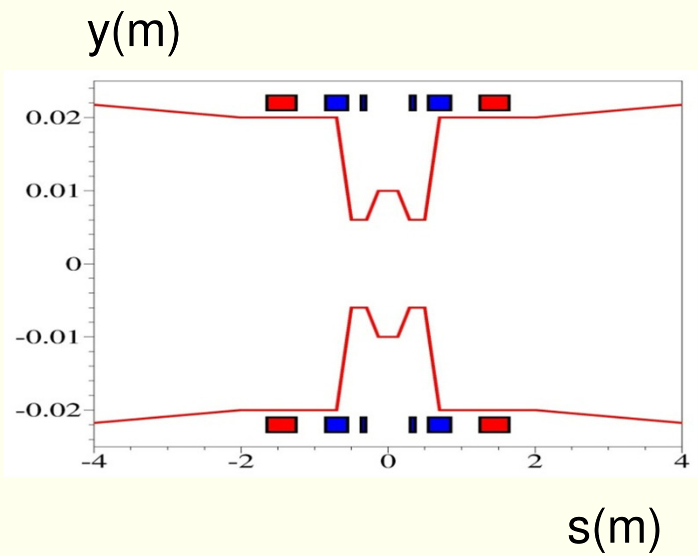
Physical aperture

- circular pipe everywhere but at IR



- At IR elliptical pipe:
- **horizontal** **vertical**

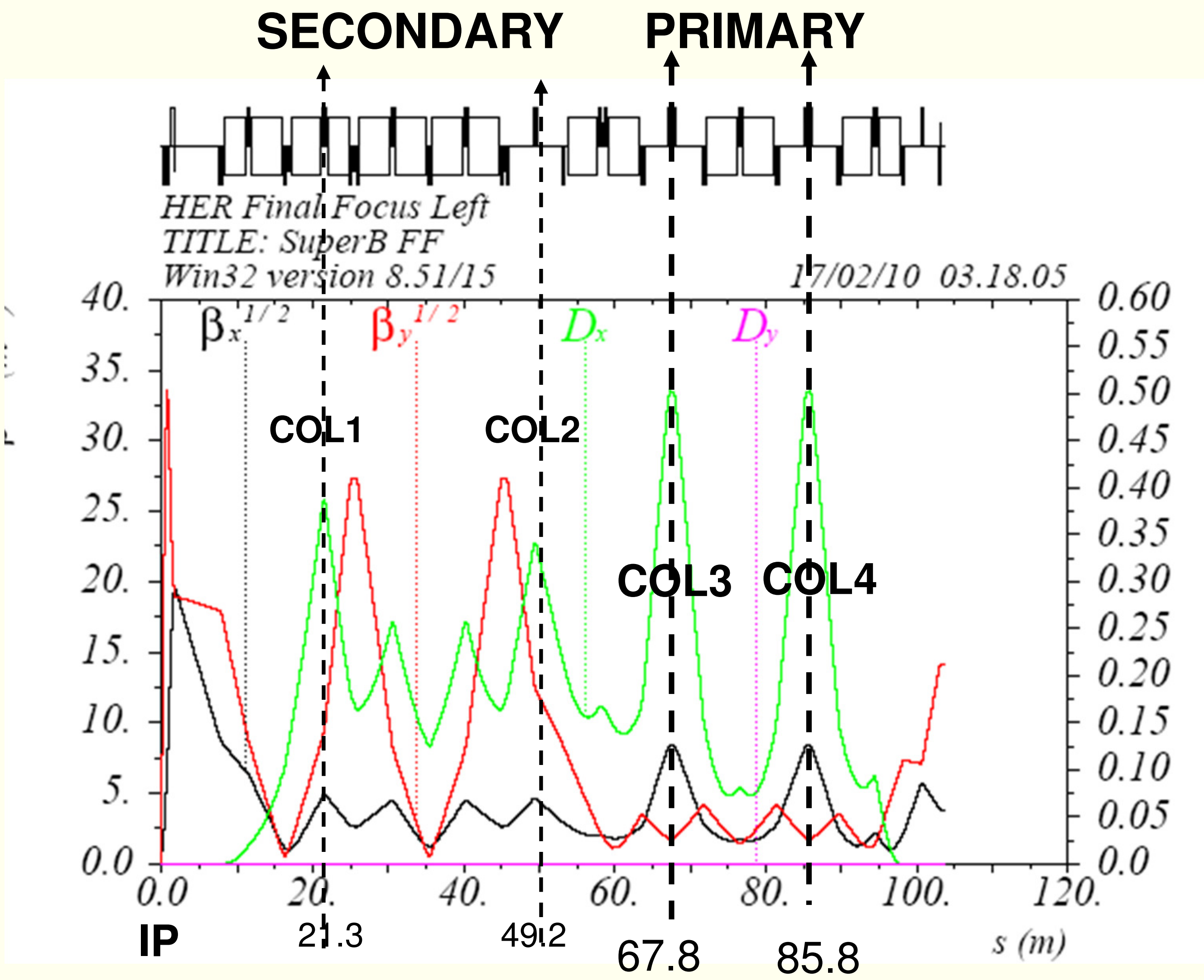




(From Mike)

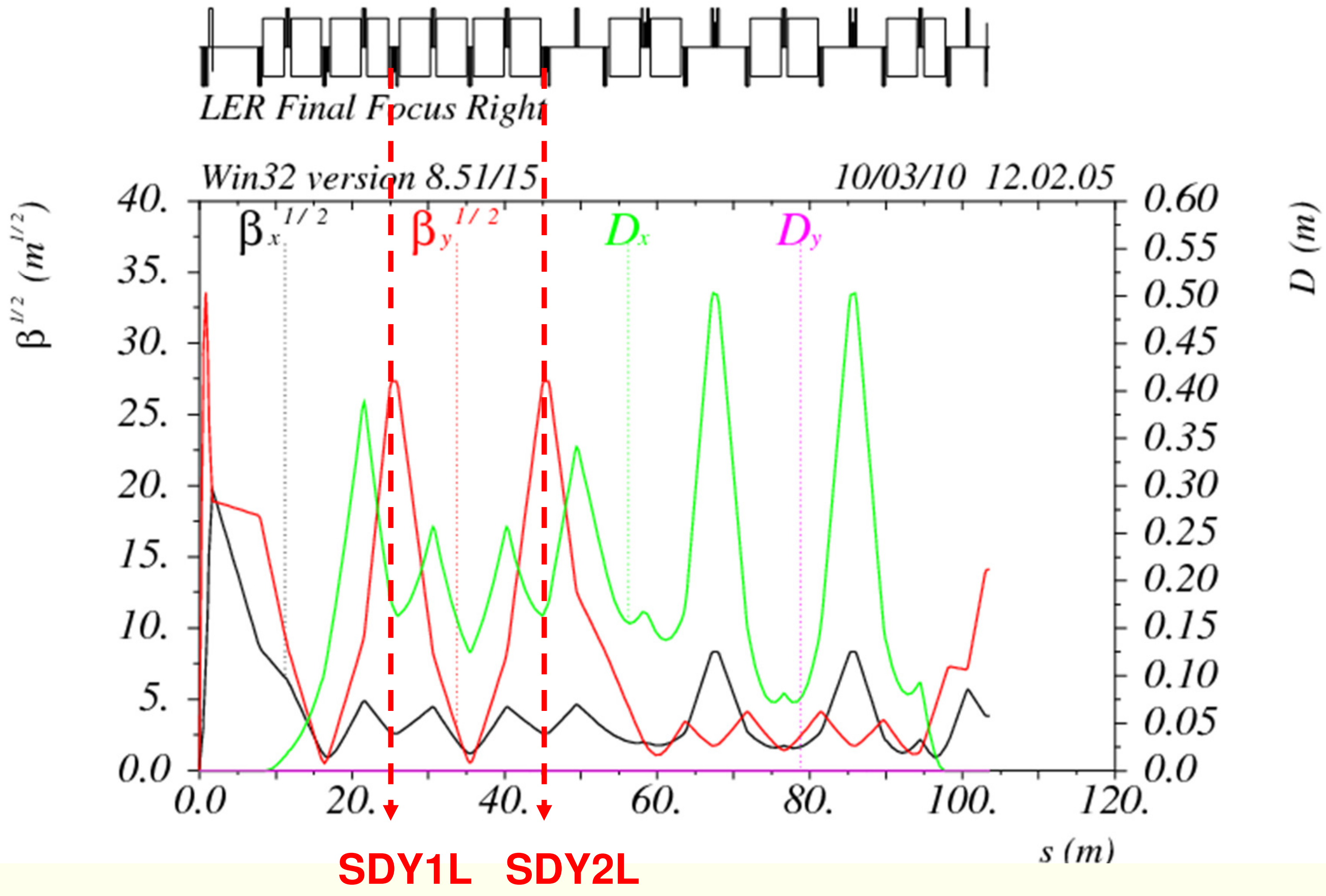
HER / LER Final Focus collimation system

Collimators are located where βx and Dx are large



Vertical COLLIMATORS in the Final Focus

To be added to the Horizontal ones, placed to intercept Touschek scattered particles



Collimators – basic idea

- The technical design will be addressed in the near future

our plan is that they should:

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

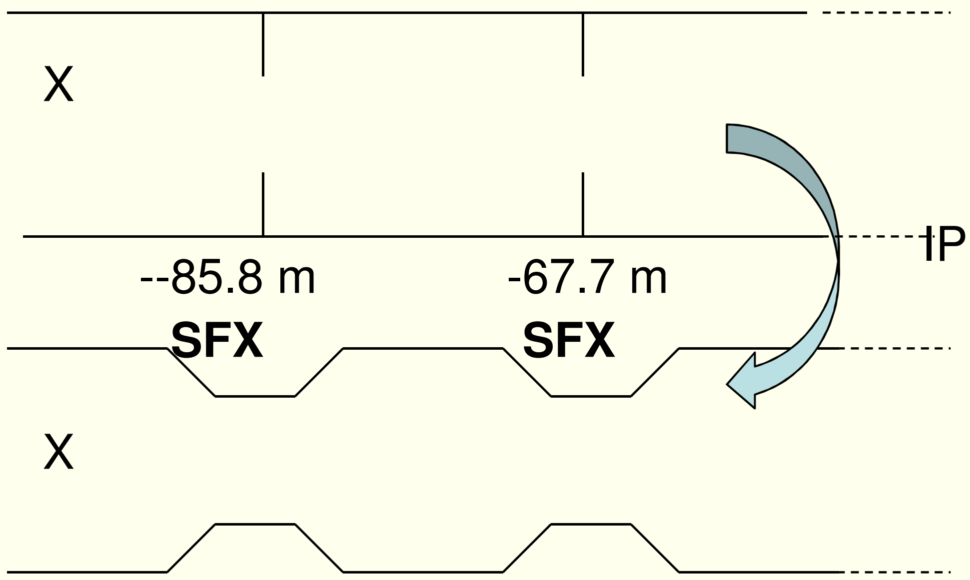
So, in principle, the good collimators set corresponds to the same Beam Stay Clear , in sigmax units, that we have in the IR

Collimator jaw insertion = 0.9* phys. aperture(QF1)·σ_{COL}/ σ_{QF1}

in the simulations an optimal position close to this value has been set

Collimators design

- The proposed **horizontal collimation system** results **very efficient** from simulations.
- Idea is **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, **and add two movable jaws as a further knob to tune IR backgrounds.**



This design has been implemented in DAFNE recently for the two most effective scrapers

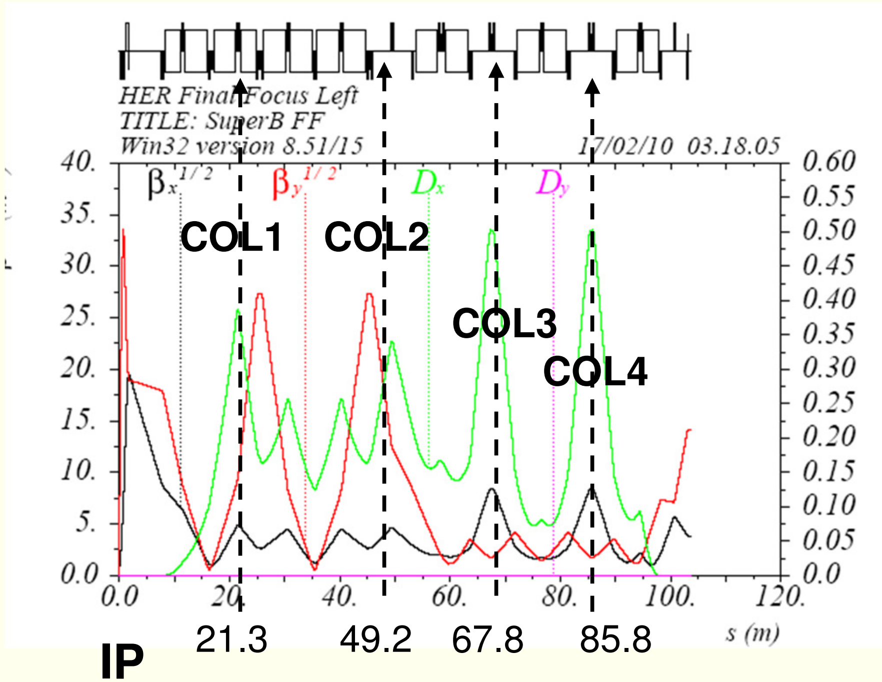
Touschek IR background rates

|s|< 2 m

HER (e+):

no collimators = 2.5 MHz × 978 bunches = 2.4 GHz/beam

with collimators = 6.95 kHz × 978 bunches = 6.8 MHz/beam



Collimator set: (mm)

	internal / external
Col1	-9 / +12
Col2	-9 / +25(out)
Col3	-18 / +12
Col4	-12 / +18

(pipe is -25 /+25 mm)

no collimators τ_{TOU} = 26 minutes

with collimators τ_{TOU} = 22 minutes

LER Touschek IR background rates

I_b =2.5 mA

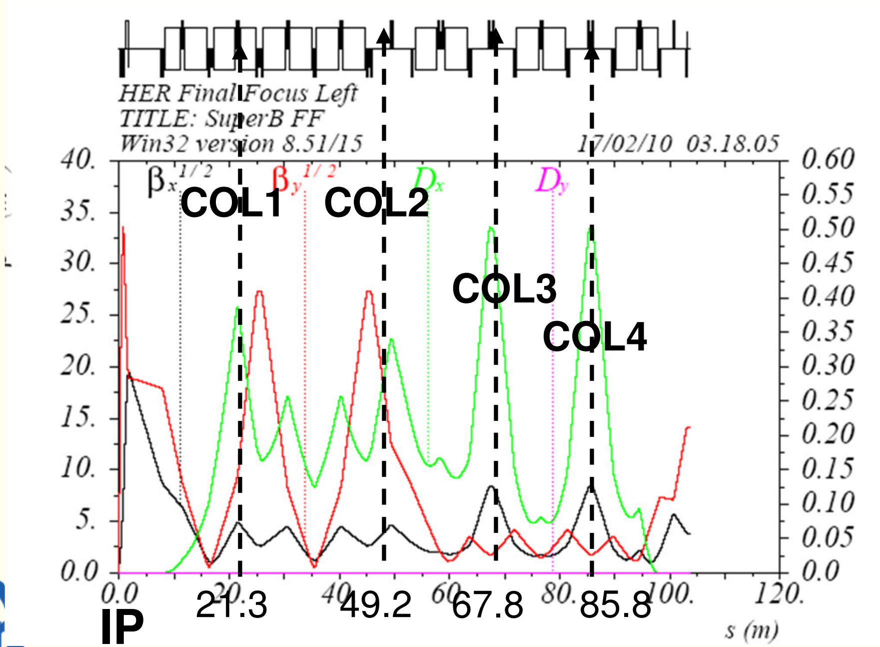
|s|< 2 m

With IBS: ε_x =2.4 nm

Collimators inserted further
With a 1.3 IR rates reduction

with collimators = 73.3 kHz/bunch × 978 bunches =72 MHz/beai

with collimators τ_{TOU} = 420 s (7 minutes)

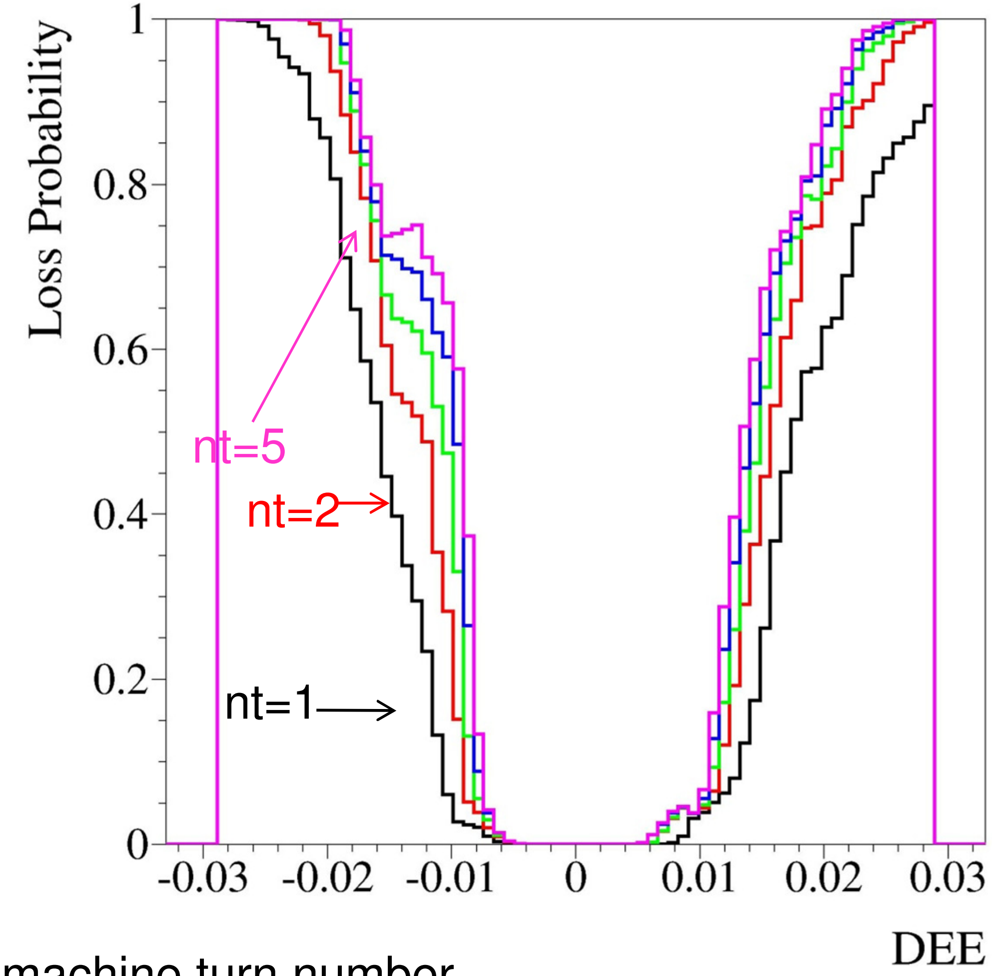


Collimator set: (mm)

	internal / external
Col1	-9 / +12
Col2	-10 / +18
Col3	(out)-25 / +12
Col4	-12 / +16

Loss probability of HER Touschek particles as a function on ΔE/E

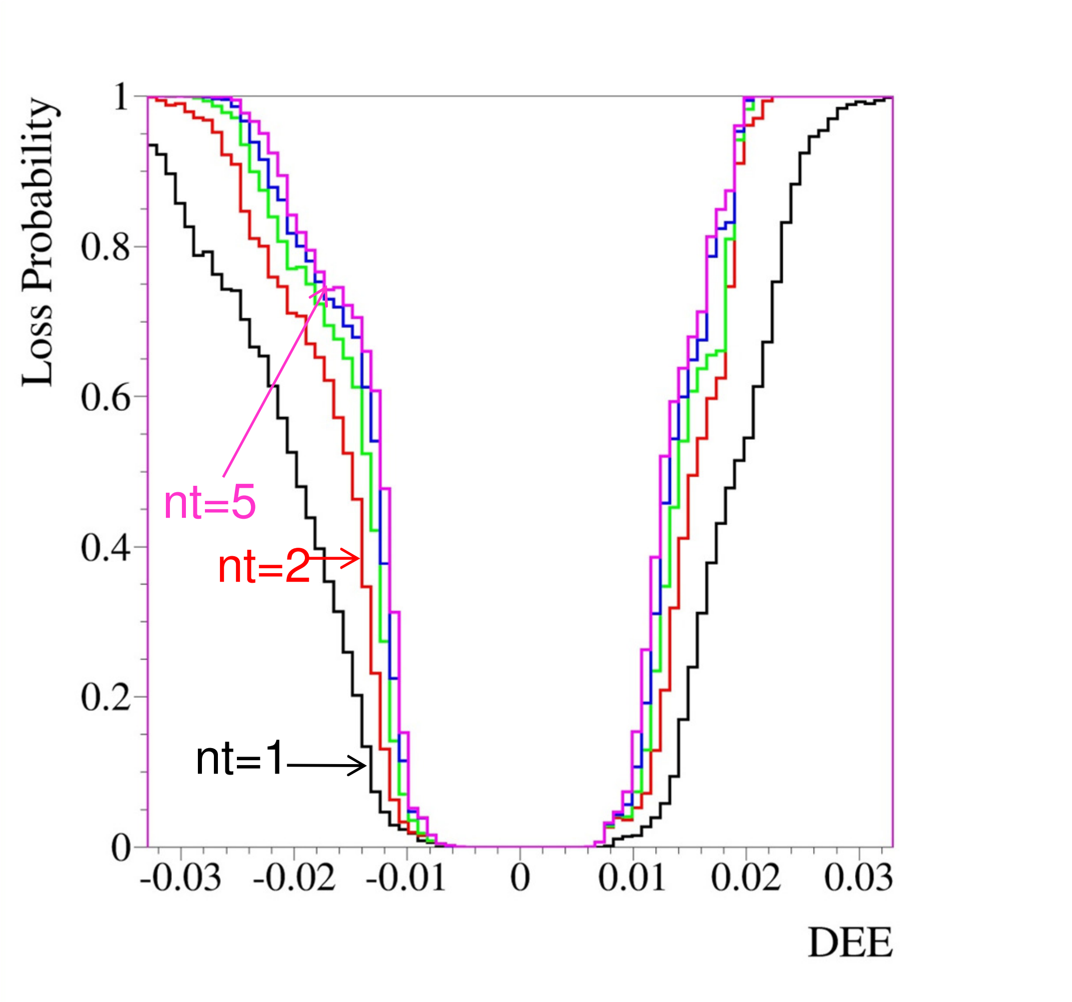
Touschek



nt= machine turn number

Loss probability of **LER** Touschek particles as a function on ΔE/E

Touschek

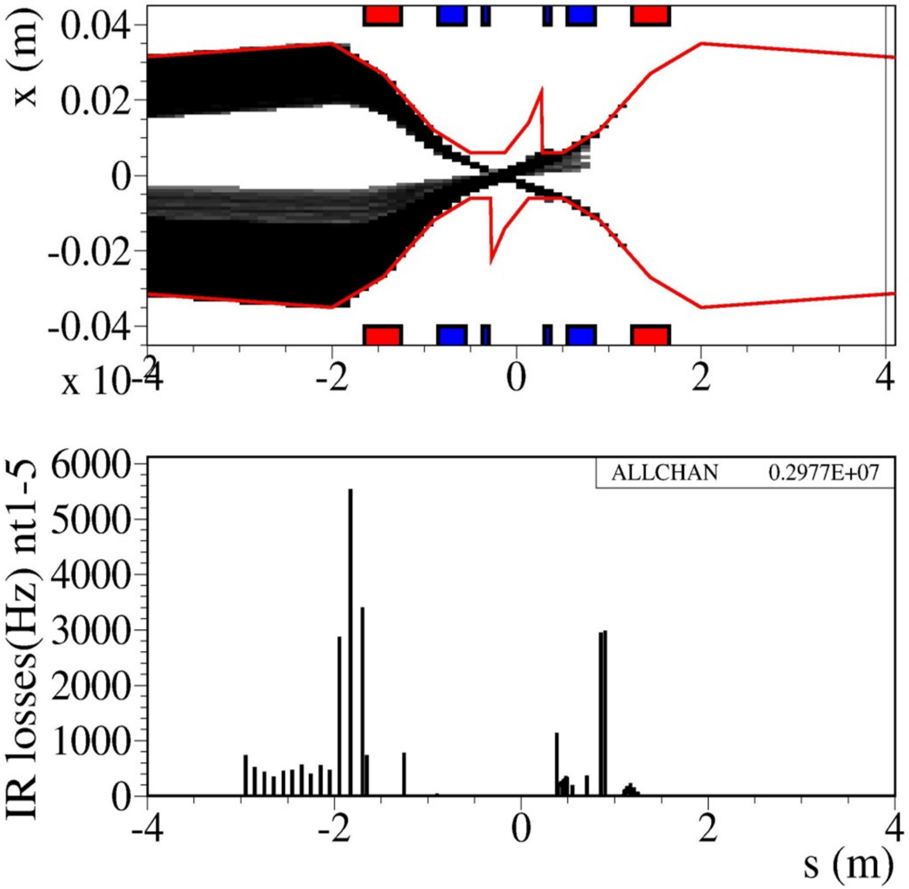


nt= machine turn number

HER IR losses (|s|< 2 m)

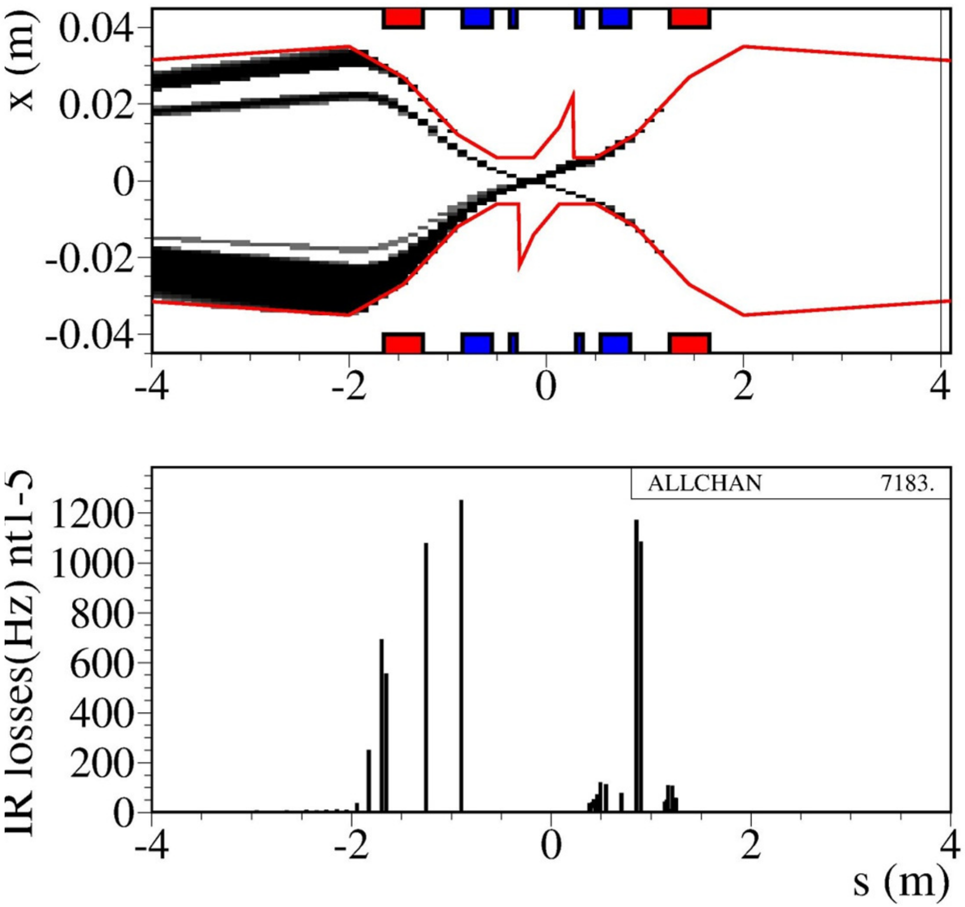
Touschek

NO collimators



IP

with collimators



IP

Collimators greatly reduce loss rates

Touschek

IR rates for the LER

I_b =2.5 mA

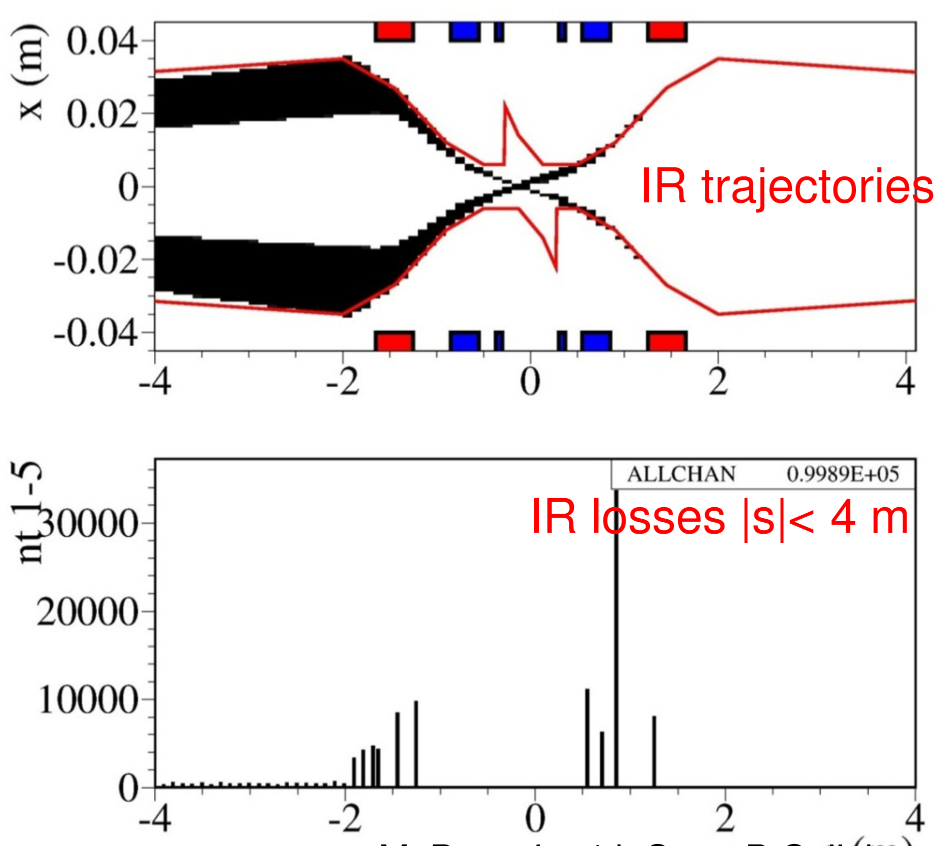
ε_x =2.4 nm

no collimators = 17.2 MHz × 978 bunches = 16.8 GHz/beam

with collimators = 93 kHz × 978 bunches = 90 MHz/beam

no collimators τ_{TOU} = 610 s (10.1 minutes)

with collimators τ_{TOU} = 470 s (7.9 minutes)



Collimator set: (mm)

	internal / external
Col1	-10 / +14
Col2	-10 / +18
Col3	(out)-25 / +12
Col4	-12 / +16

careful study of secondaries into sub-detectors indicated these rates were a bit too high

HER Beam-gas Coulomb scattering

P = 1 nTorr constant along ring, Z = 8

HER	τ (s)	IR losses/beam
no collimators	4590	10.5 GHz
with vertical Collimators	**3040**	**3.7 MHz**

About a factor 950 in IR losses reduction

no collimators =10.8 MHz/bunch × 978 bunches=10.5GHz/beam

with collimators = 3.8 kHz/bunch × 978 bunches= 3.7 MHz/beam

Collimator set: (mm)	internal / external
HCol1	-9 / +12
HCol2	-9 / +25(out)
HCol3	-18 / +12
HCol4	-12 / +18
VCol1	**-4.5 / +4.5**
VCol2	**-4.5 / +4.5**

Set of values optimized for Touschek (HCol1–HCol4)

LER Beam-gas Coulomb scattering

P = 1 nTorr constant along ring, Z = 8

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

↓ About a factor 700 in IR losses reduction

no collimators = 26 MHz/bunch × 978 bunches =25.4 GHz/beam

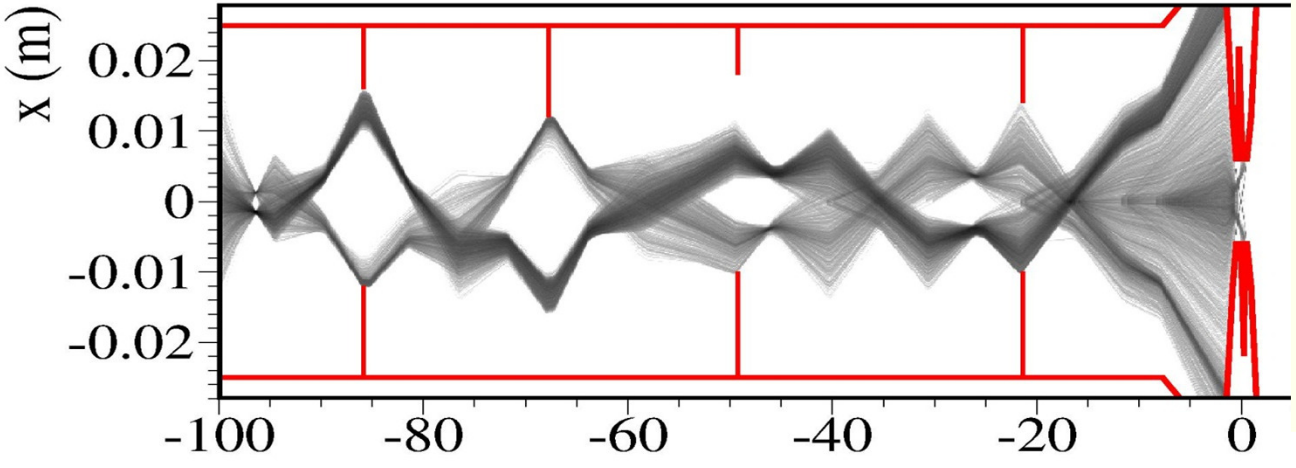
with collimators = 36.7 kHz/bunch × 978 bunches=36 MHz/beam

Collimator set: (mm)	internal / external
HCol1	-10 / +14
HCol2	-10 / +18
HCol3	(out)-25 / +12
HCol4	-12 / +16
VCol1	**-6 / +6**
VCol2	**-6 / +6**

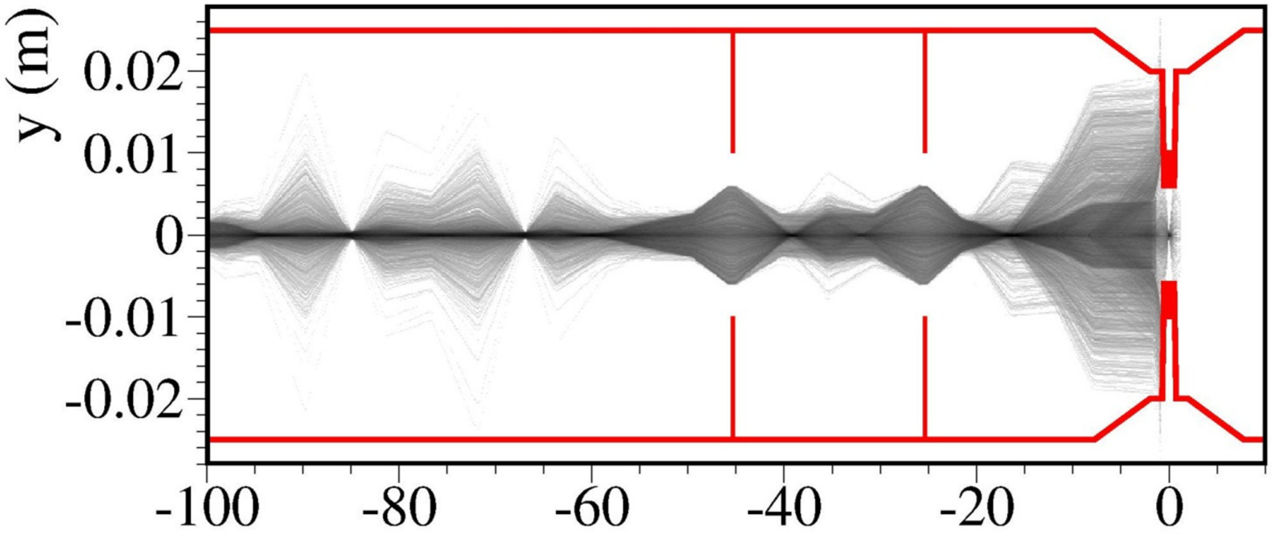
There is margin of further IR rate reduction,
As for the HER, Vcol set may be re-checked if secondaries not satisfactory (we still have margin in lifetime)

Coulomb scattered particles lost at IR

Trajectories of scattered particles eventually lost at IR



horizontal



vertical

s(m)