SuperB Touschek and beam-gas background

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3rd SuperB Collaboration Meeting
Frascati
March 19th – 23rd 2012

Outline

- Introduction

- Touschek generator
- Collimation system (horizontal)
- Touschek simulation results for LER & HER

- Beam-gas generator
- Collimation system (vertical)
- Beam-gas simulation results for LER & HER

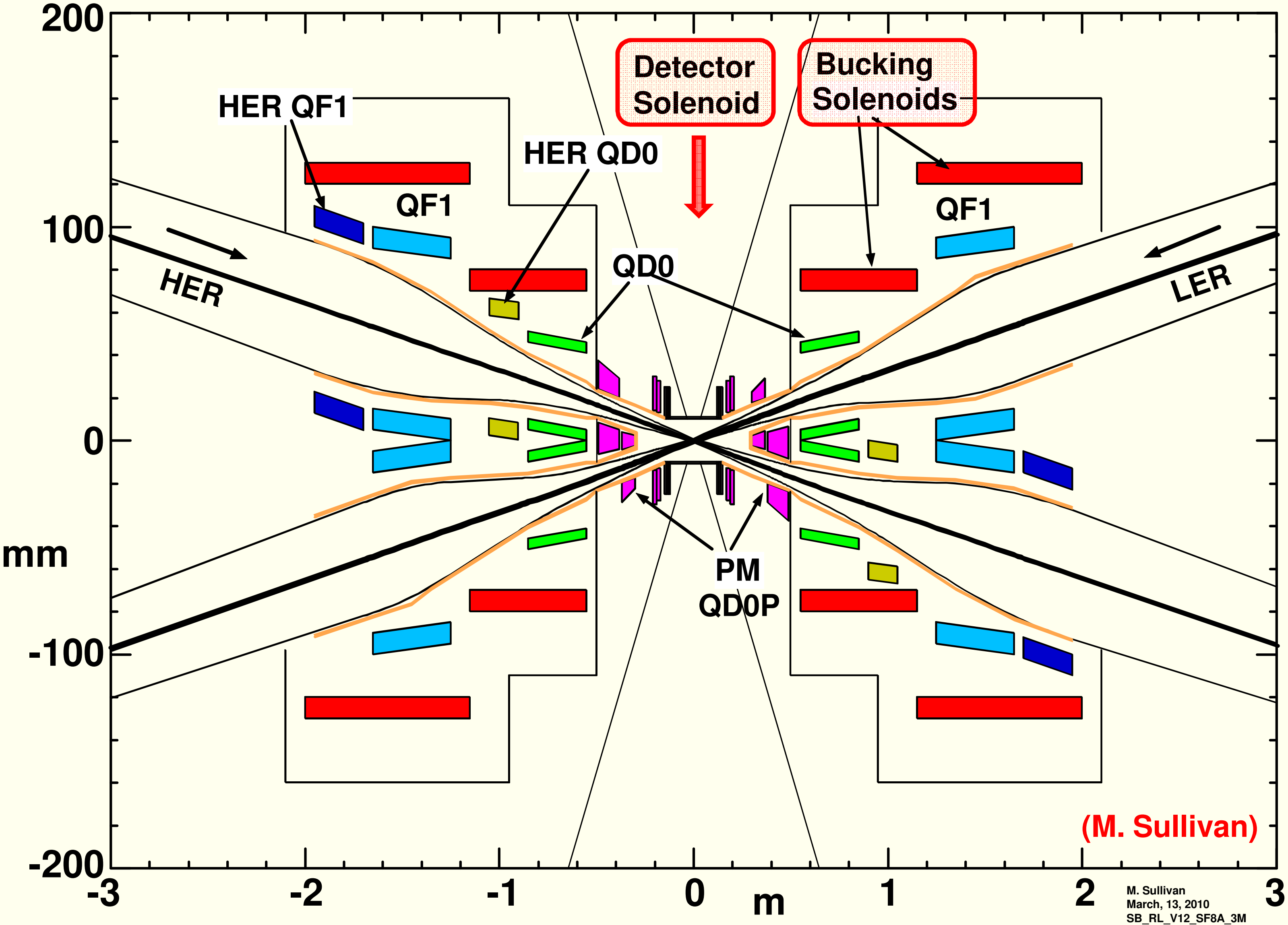
Introduction

- The main sources of loss rates are under control and secondaries tracked into sub-detectors and their effects evaluated

- In the next months we will freeze lattice design:
  if needed, we'll update backgrounds simulations,
  some minor changes are expected

- **Present Status 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



About Touschek Simulation

- 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

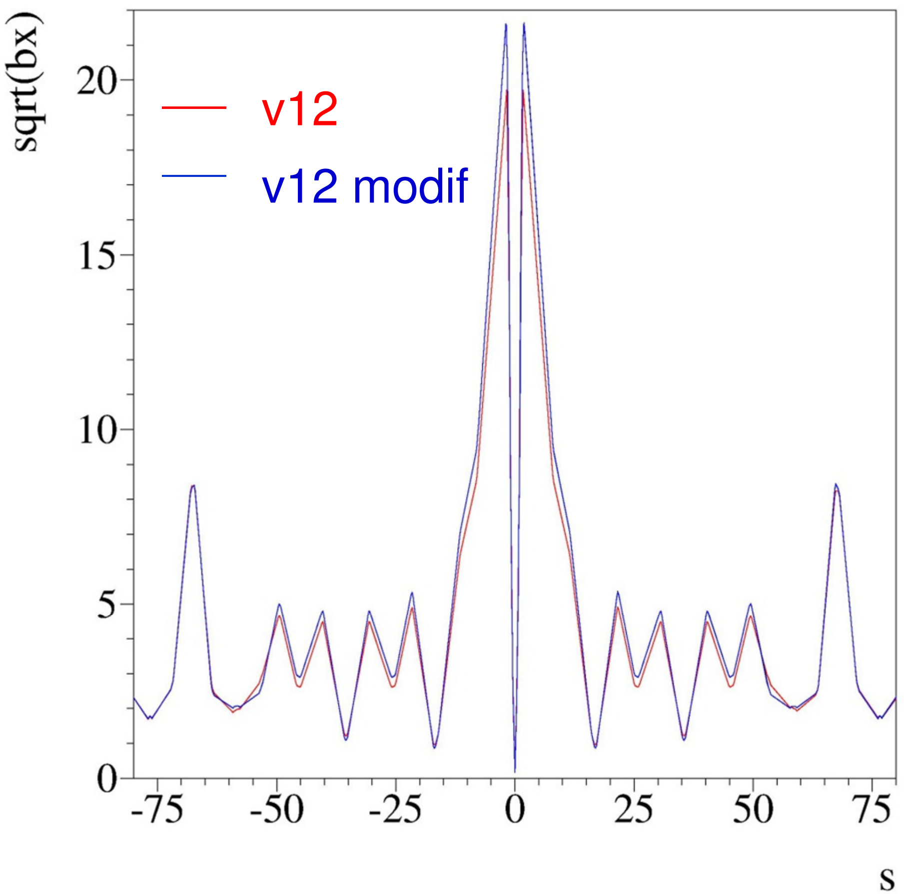
- stable results with few (~5) machine turns
- stable results with about 10^6 macroparticles
  - 500particles x 2 (DE/E>0, DE/E<0) every 3elements out of 2300 (≈0.8e6 tracked)

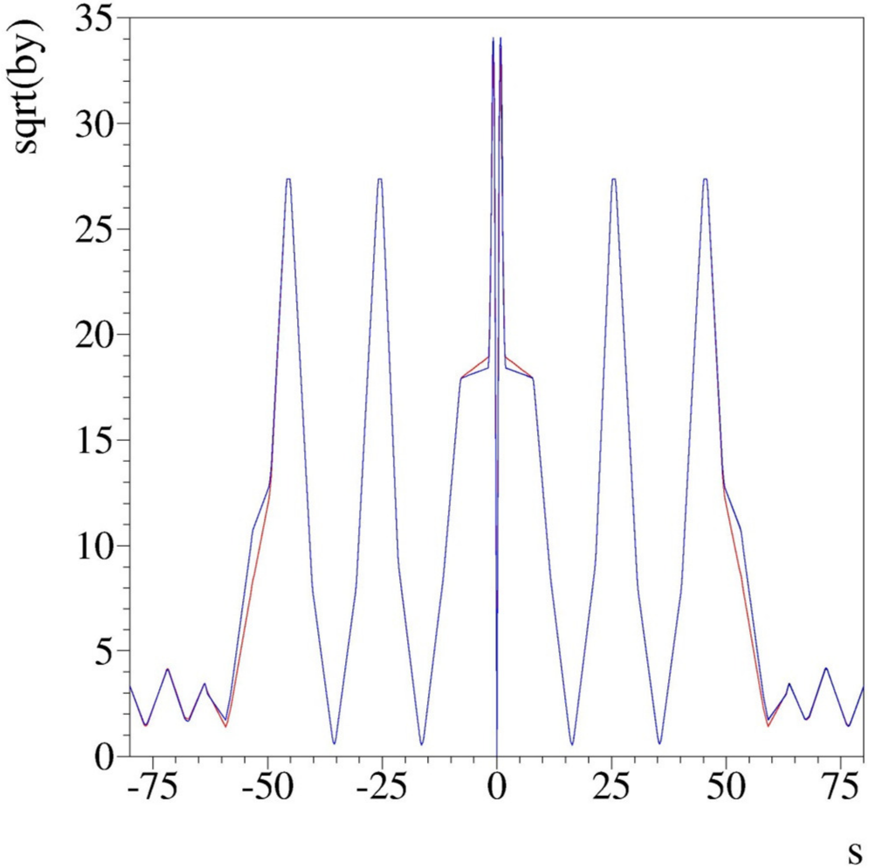
Parameters used in the IR designs

(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		

HER Optics: zoom of Final Focus

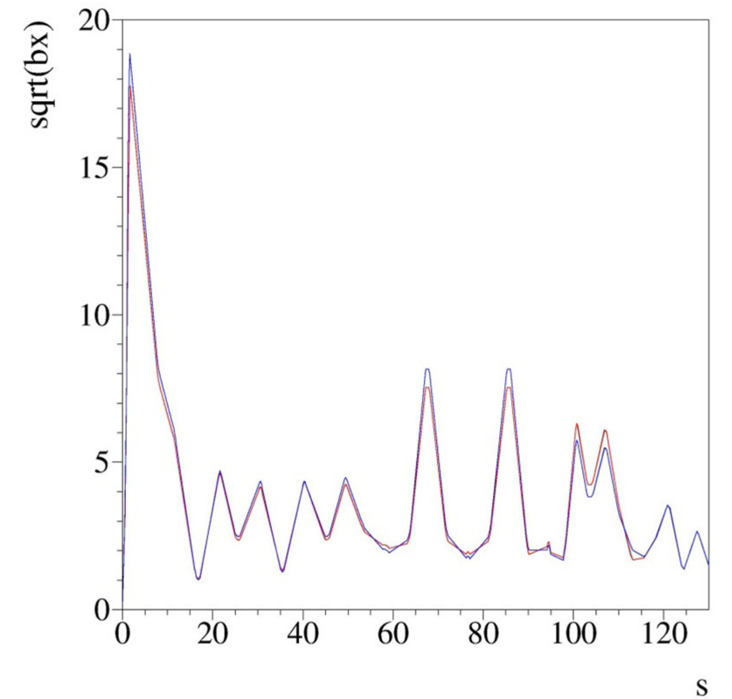


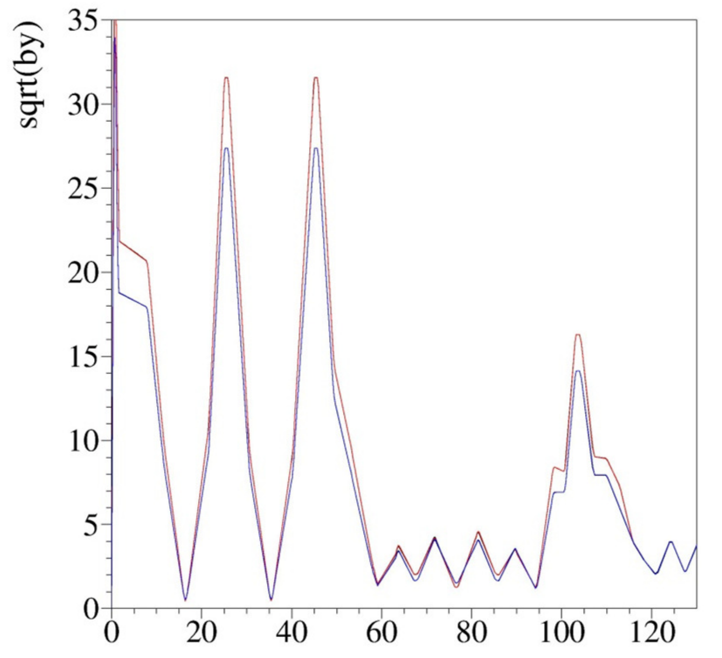


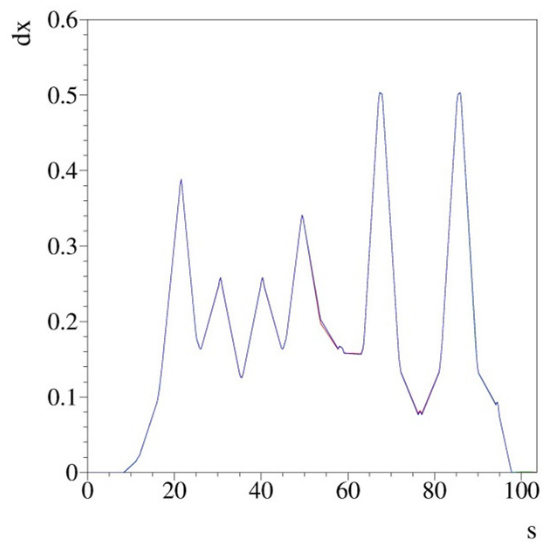
beta_x* = 2.6cm
beta_y* = 0.27mm

beta_x* = 2.6cm
beta_y* = 0.27mm

LER Optics: Final Focus







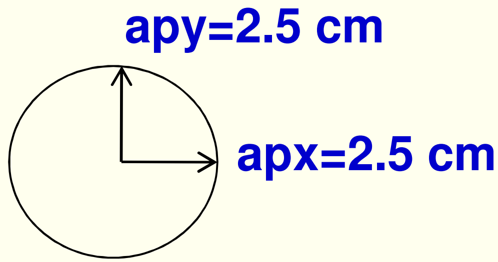
—— v12 beta_x* = 3.2cm
beta_y* = 0.206mm

Nominal values

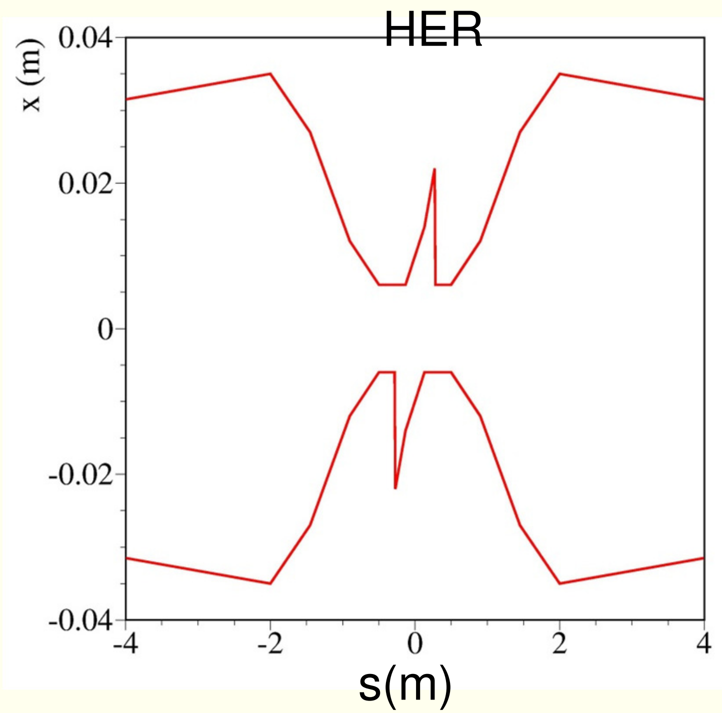
—— v12 modif beta_x* = 2.6cm
beta_y* = 0.274mm

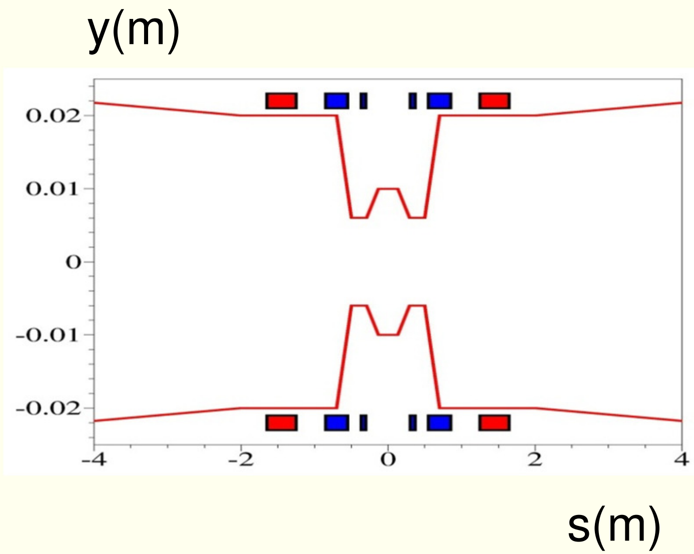
Physical aperture

- circular pipe everywhere but at IR



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

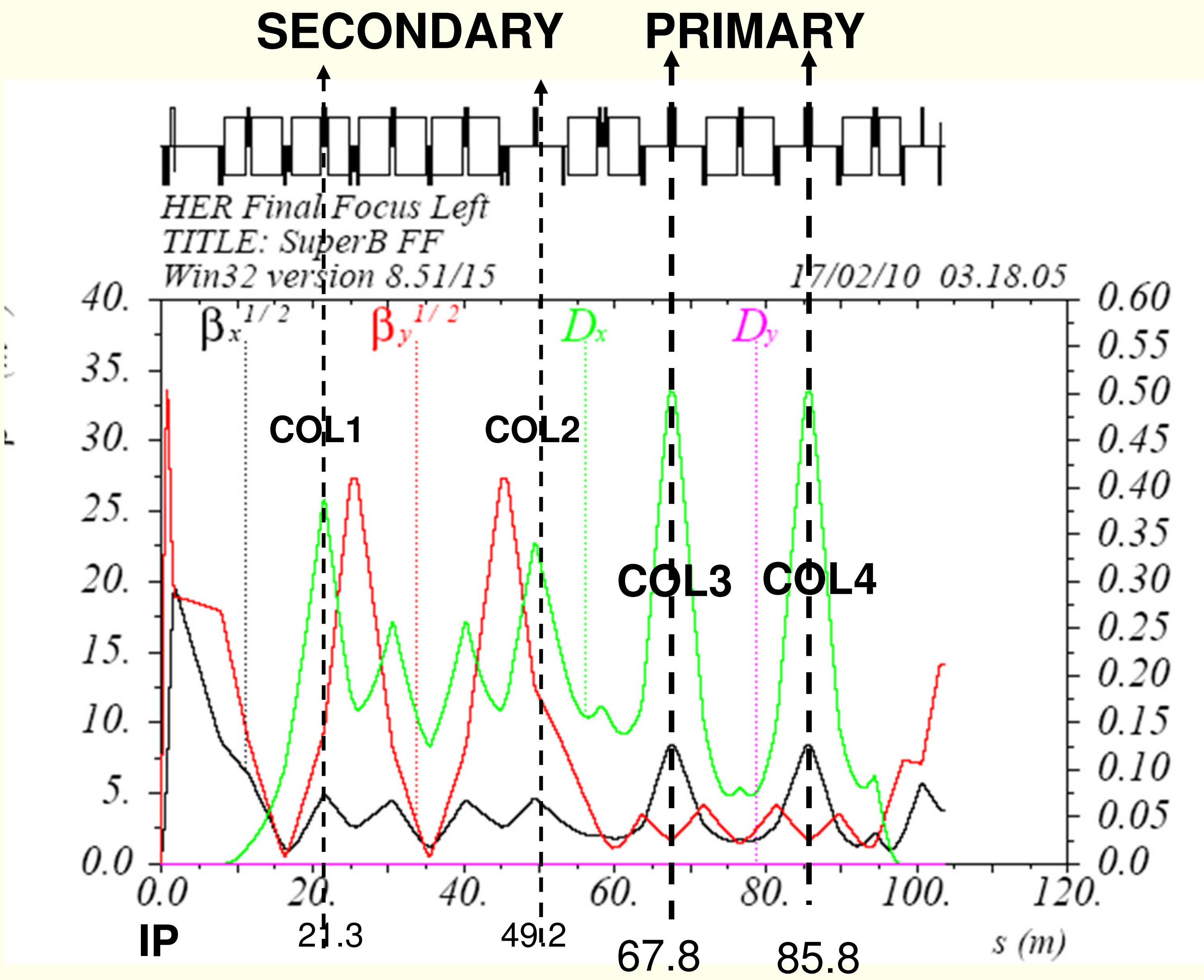




(From Mike)

HER / LER Final Focus collimation system

Collimators are located where βx and Dx are large



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

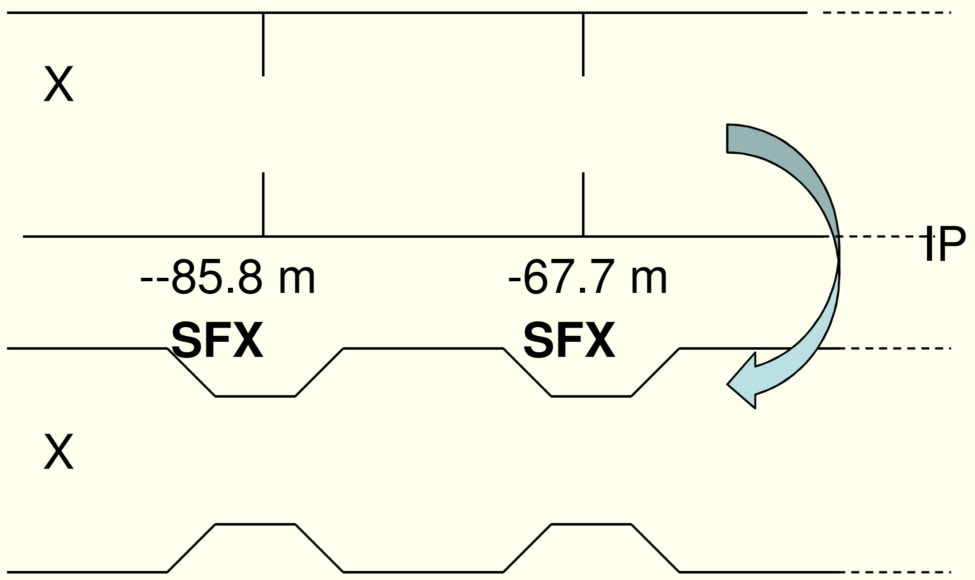
So, in principle, the good collimators set corresponds to the same Beam Stay Clear , in sigmax units, that we have in the IR

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

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

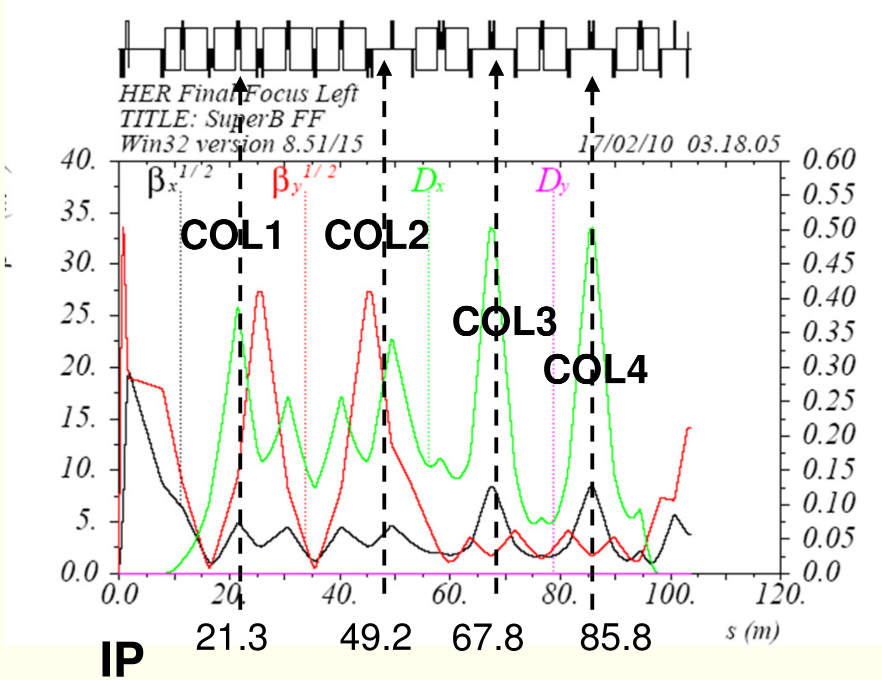
Touschek IR background rates

|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

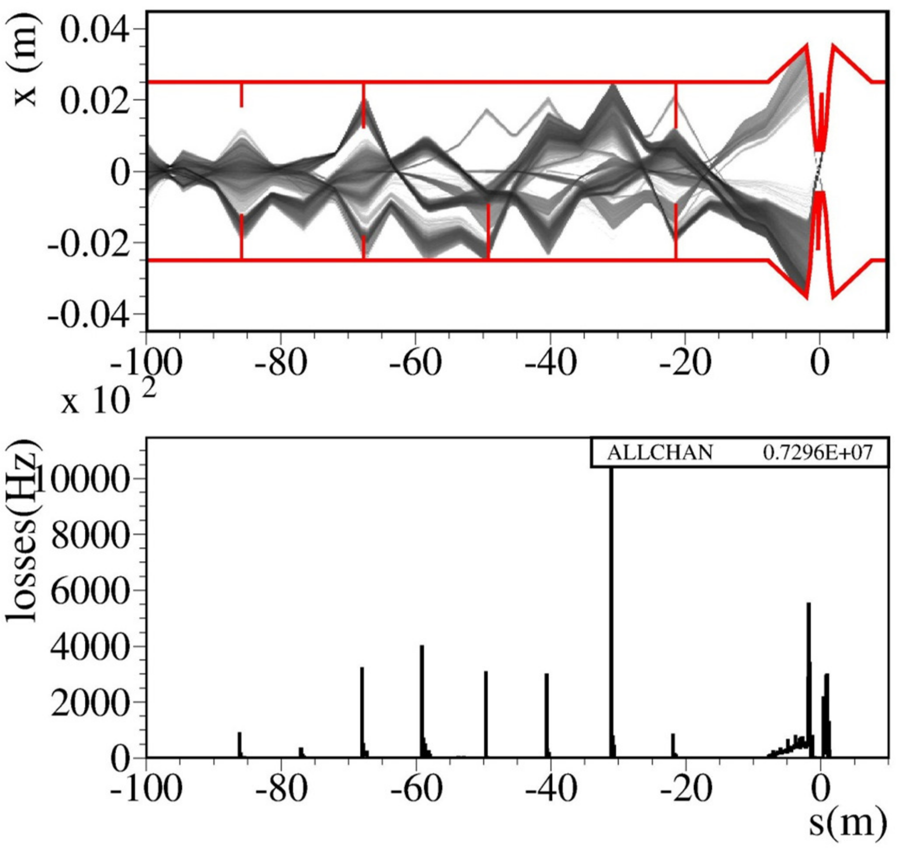
(pipe is -25 /+25 mm)

no collimators τ_{TOU} = 26 minutes

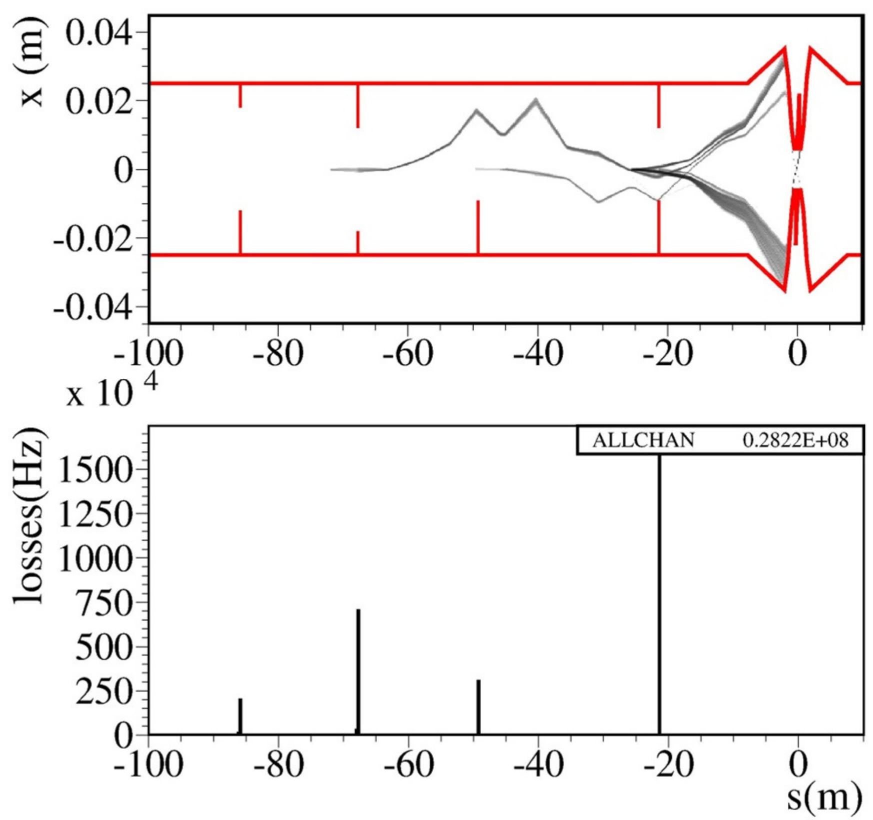
with collimators τ_{TOU} = 22 minutes

HER v12modif Touschek Trajectories

No collimators



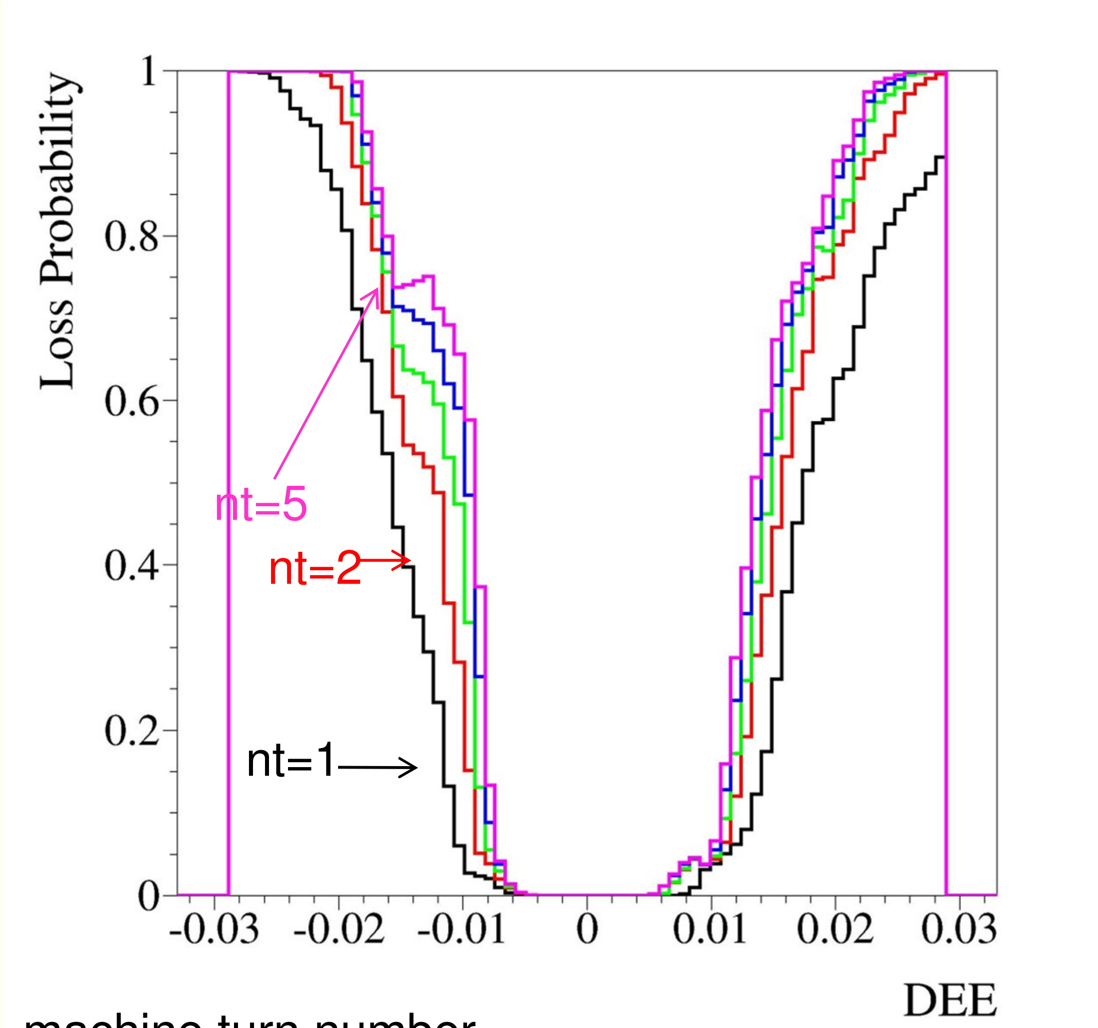
with collimators



found by minimizing IR rates and maximizing lifetime

real set will be found experimentally

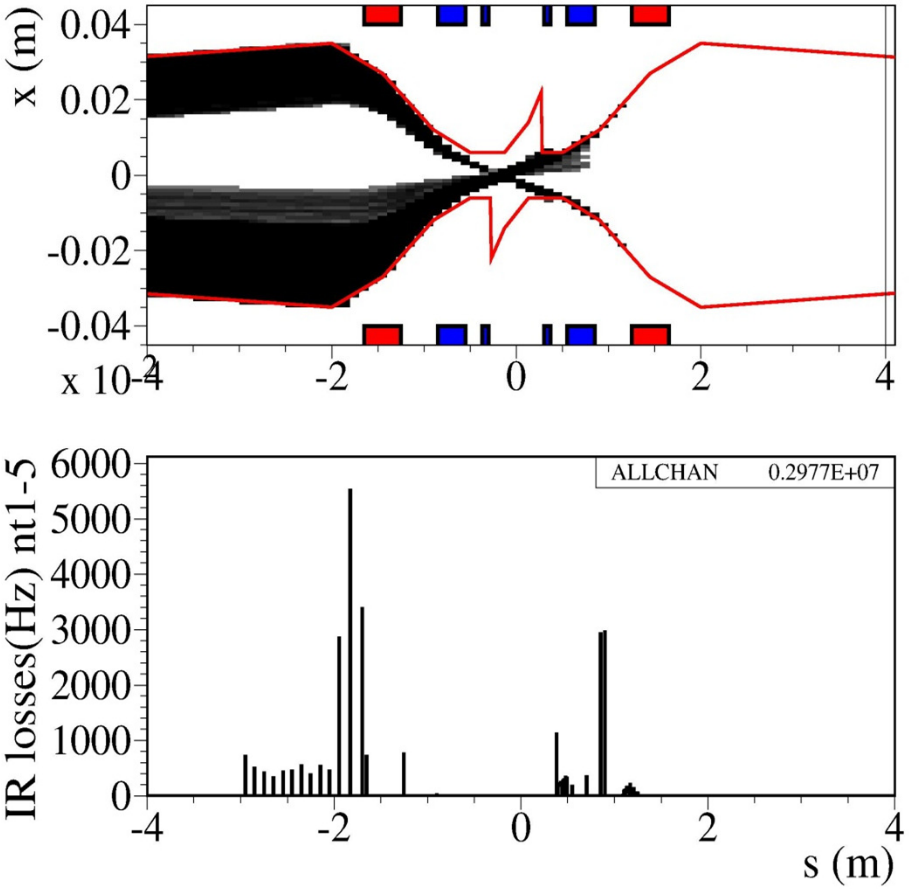
Loss probability of HER Touschek particles as a function on ΔE/E



nt= machine turn number

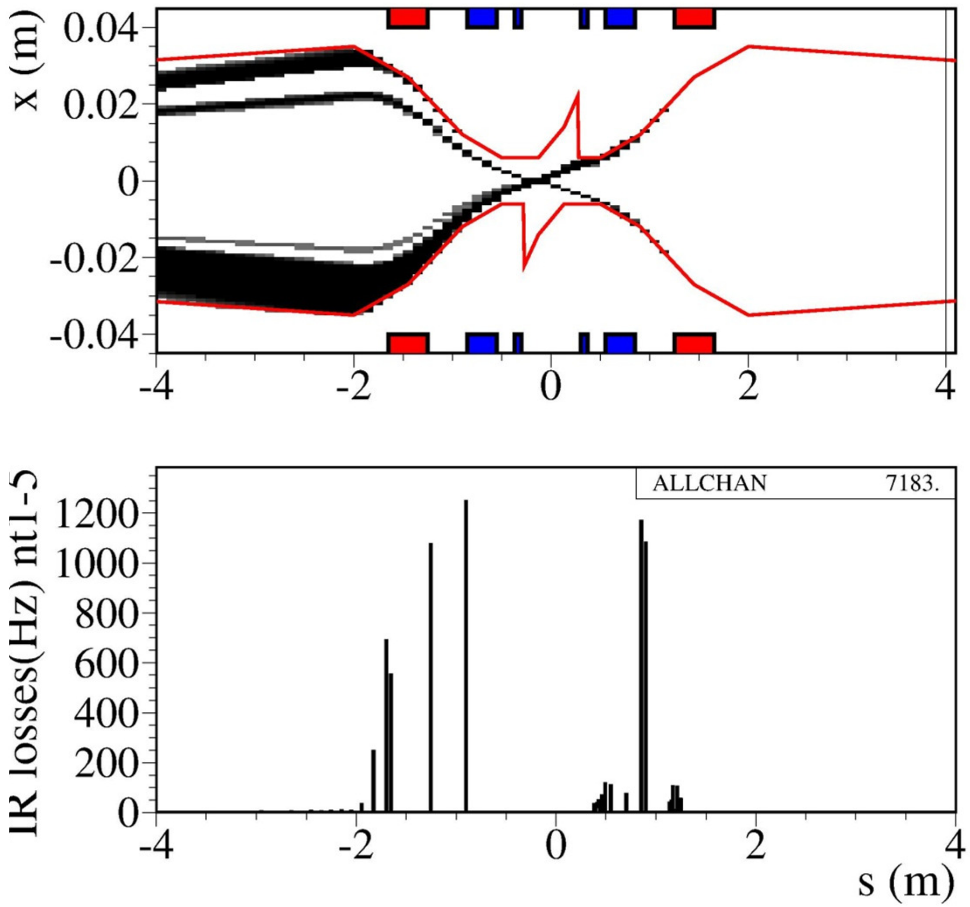
HER IR losses (|s|< 2 m)

NO collimators



IP

with collimators



IP

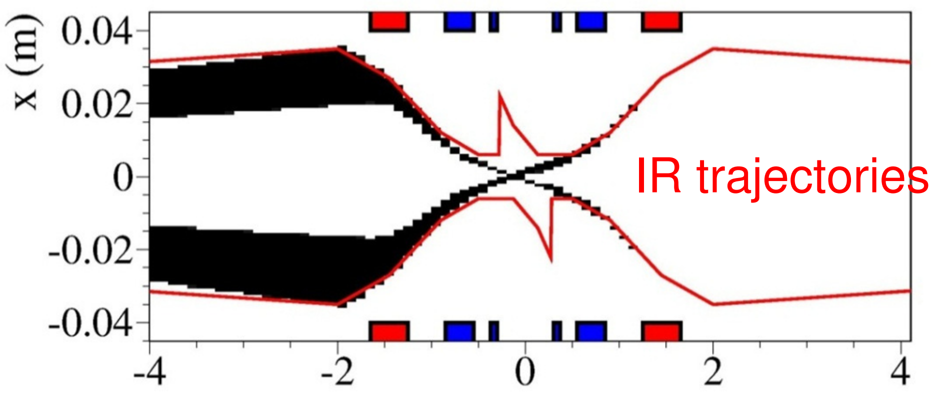
Collimators greatly reduce loss rates

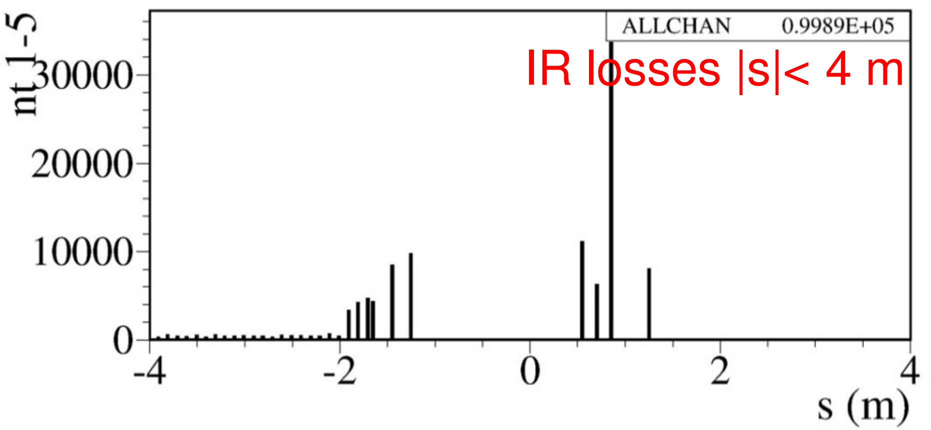
IR rates for the LER

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)



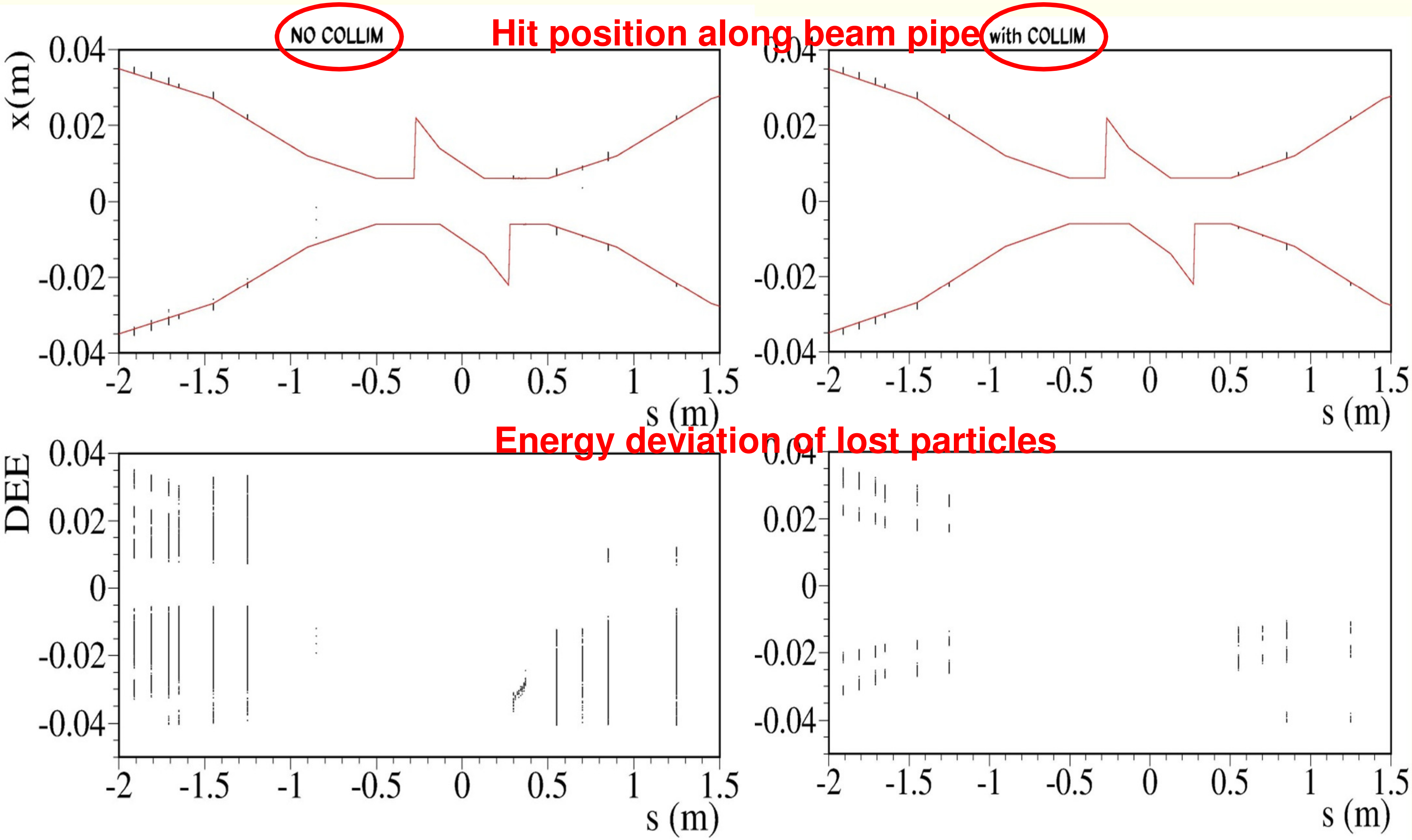


Collimator set: (mm)

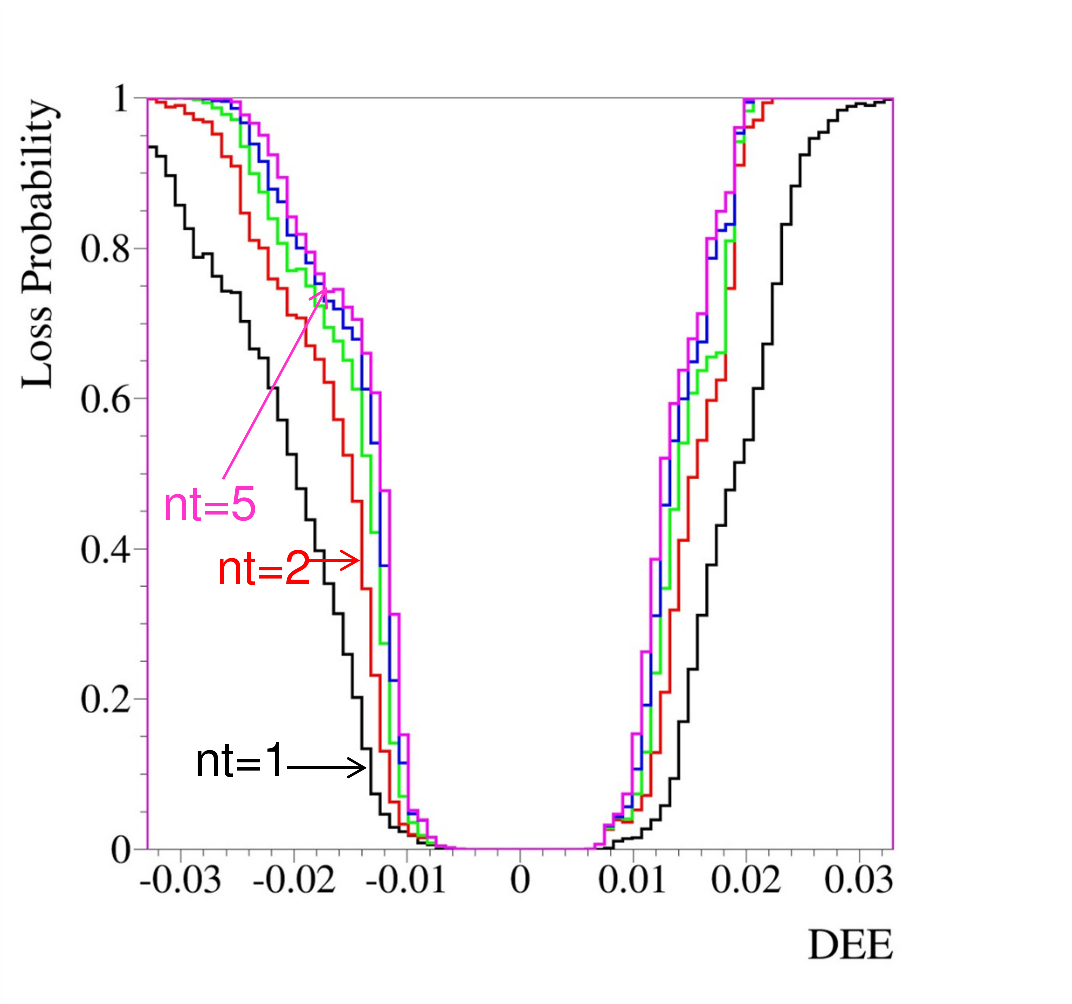
	internal / external
Col1	-10 / +14
Col2	-10 / +18
Col3	(out)-25 / +12
Col4	-12 / +16

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

IR lost particles of the LER



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



nt= machine turn number

LER Touschek IR background rates

I_b =2.5 mA

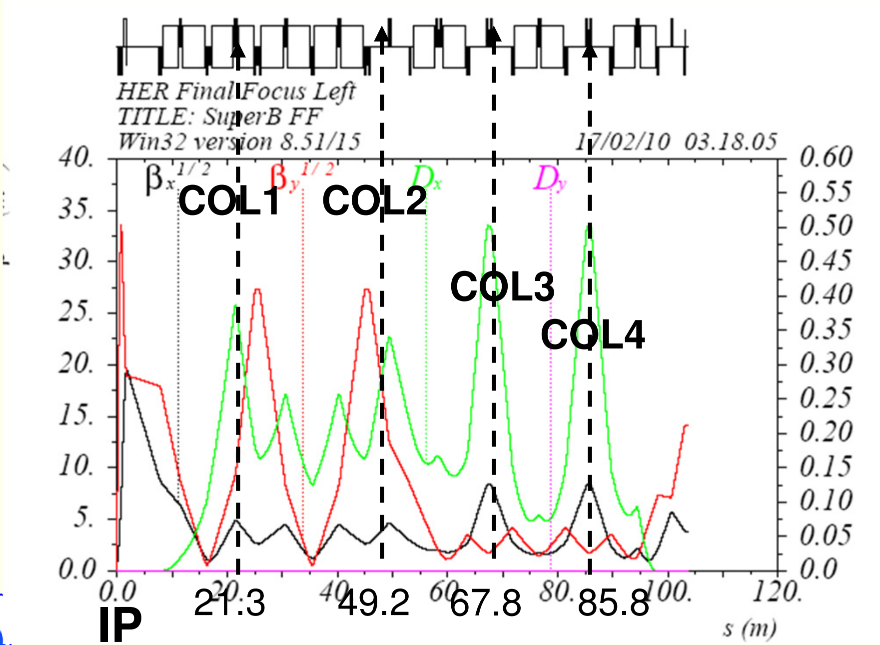
|s|< 2 m

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/beam

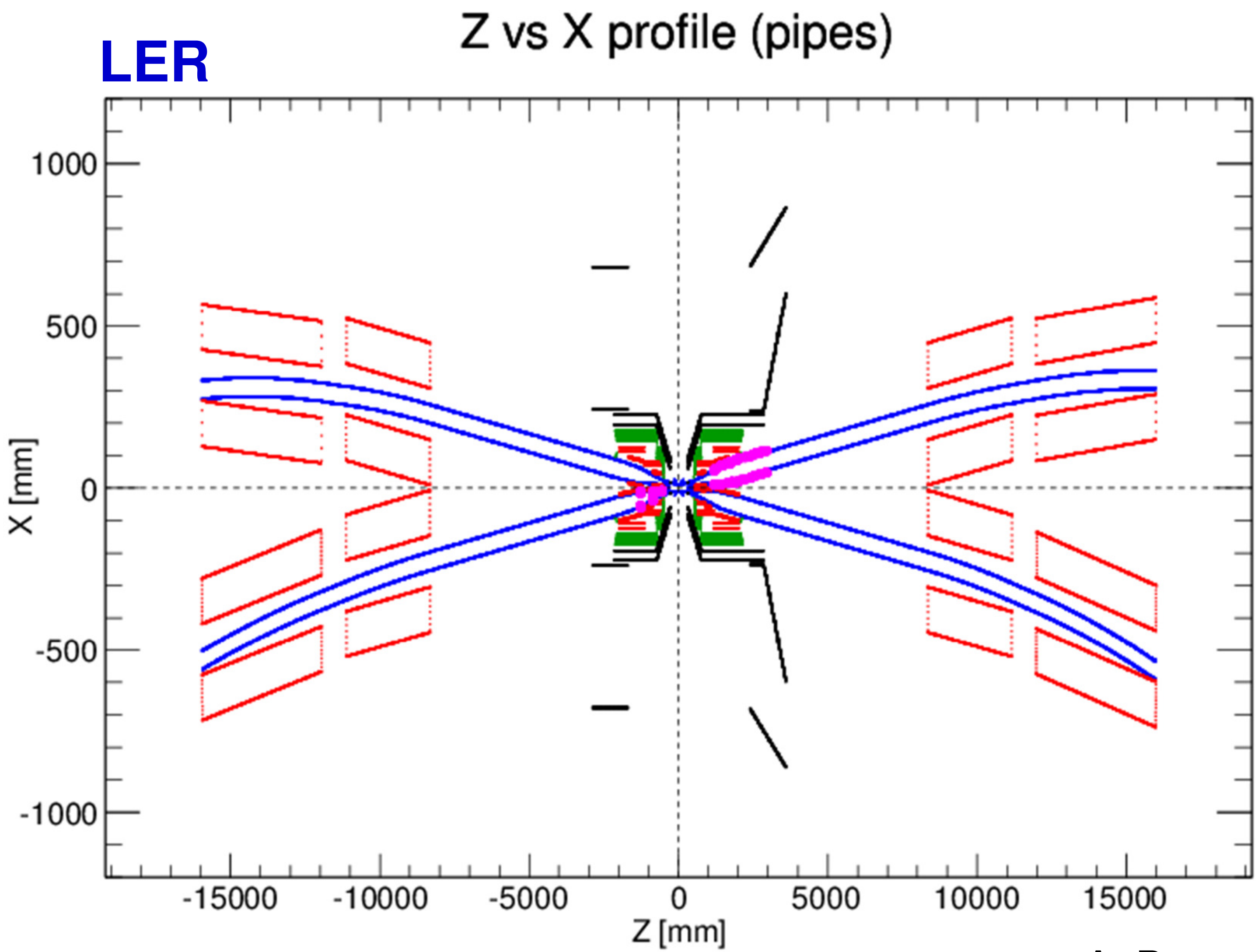
with collimators τ_{TOU} = 420 s (7 minutes)



Collimator set: (mm)

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

Touschek particles hitting the pipe: full geometry before tracking

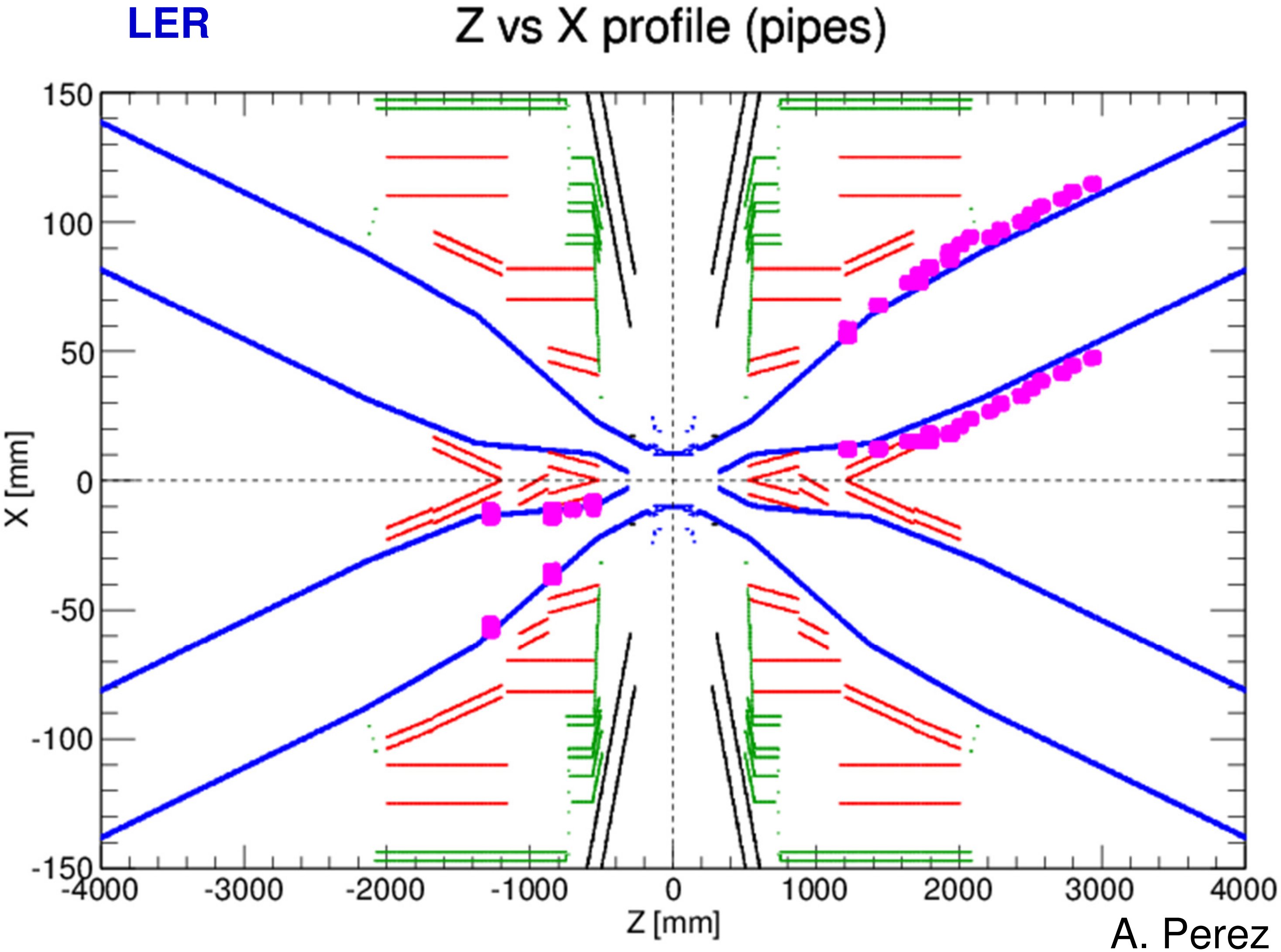


A. Perez

Touschek particles hitting the pipe: full geometry before tracking

Zoom within 4 m

LER



A. Perez

Beam-gas scattering

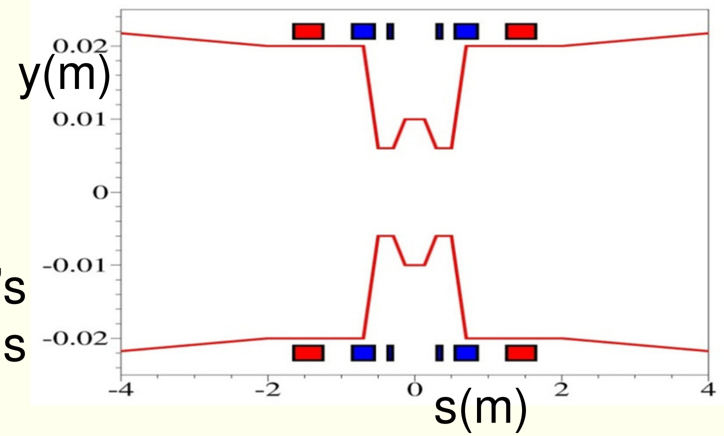
The same MonteCarlo approach as for Touschek simulation is used by substituting the elastic/ inelastic differential cross-section to the Touschek cross-section

Beam-gas bkg –general considerations

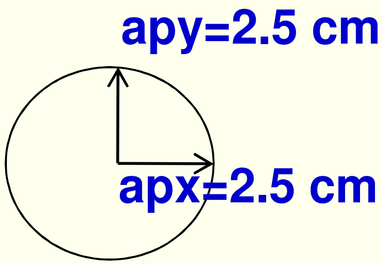
- Particle losses expected vertically, at the QD0

  beam pipe is assumed circular all along the ring

  But at the IR:



plot from M. Sullivan's stay-clear evaluations



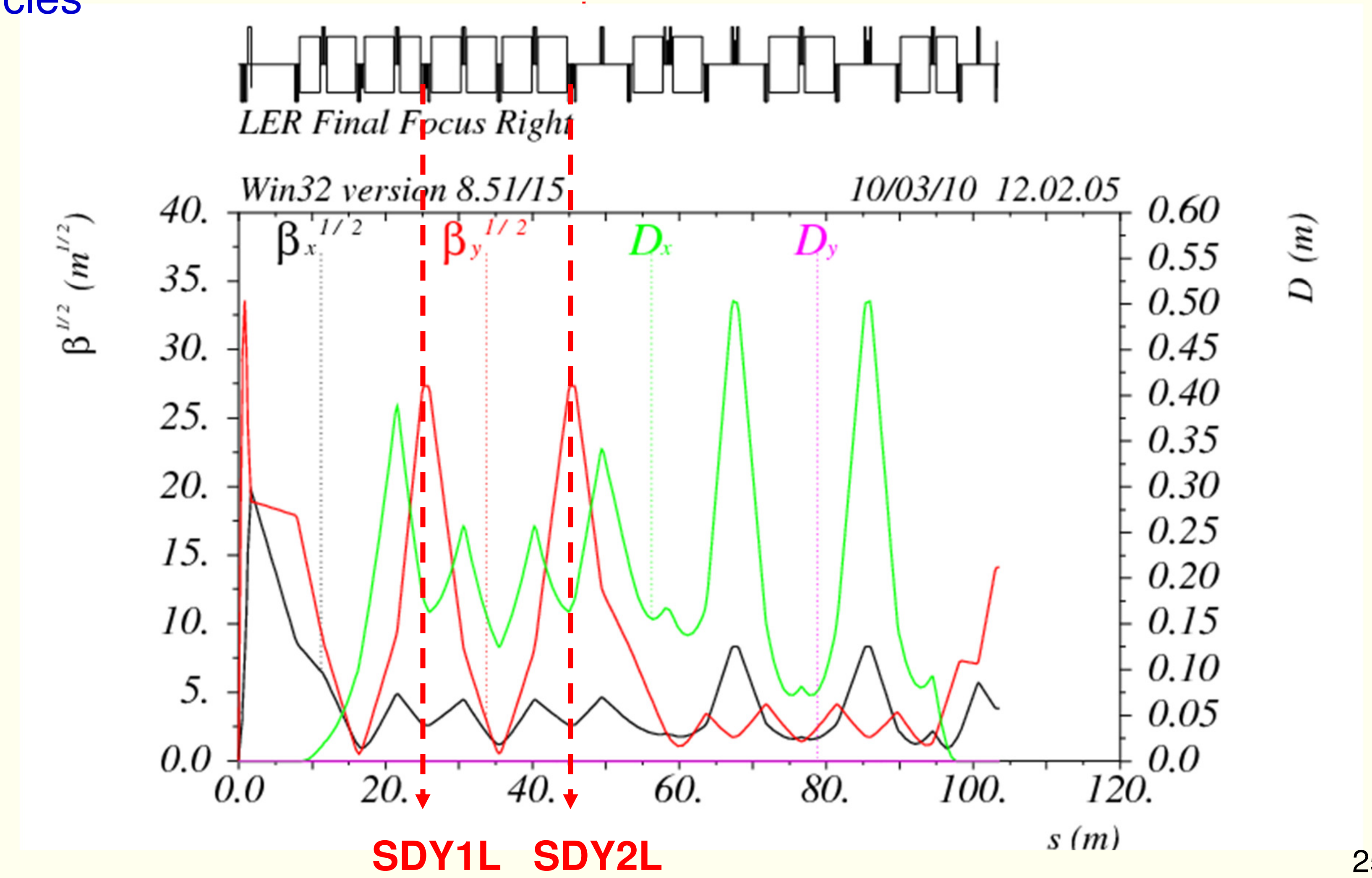
- Beam-gas is very much dependent on how good vacuum is:

  P=1nTorr constant up to now,

  different pressures along ring, especially at IR, planned

Vertical COLLIMATORS in the Final Focus

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



Following the same criteria used for horizontal collimators:

Vertical Collimators upstream the IR

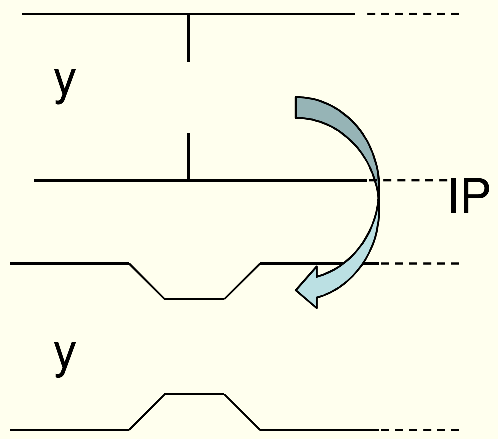
Intercept the scattered particles
in the final focus upstream the IR
that otherwise would be lost at the QD0

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

IR losses are greatly reduced by these Vertical collimators placed with this criteria

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, **and add two movable jaws as a further knob to tune IR backgrounds.**



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)

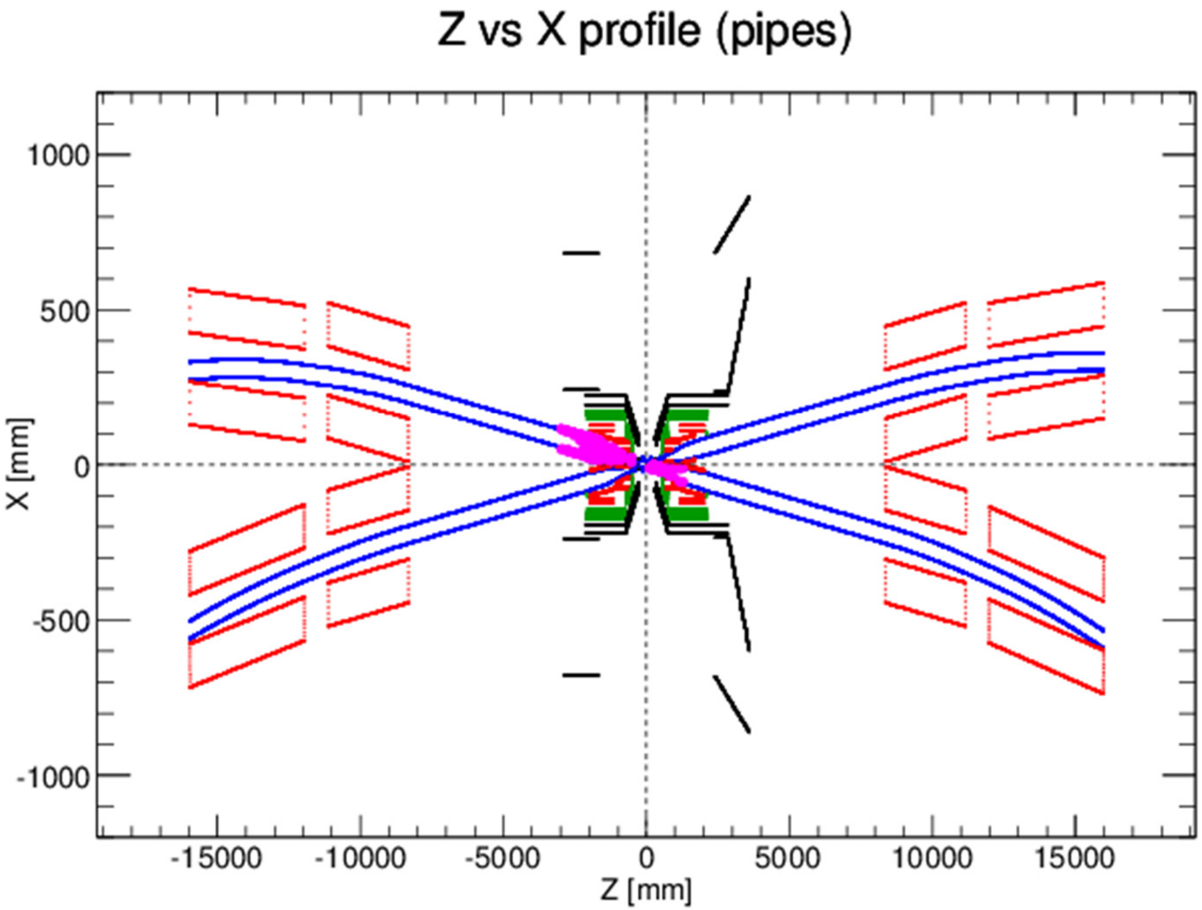
	internal / external
HCol1	-9 / +12
HCol2	-9 / +25(out)
HCol3	-18 / +12
HCol4	-12 / +18
VCol1	**-4.5 / +4.5**
VCol2	**-4.5 / +4.5**

Set of values optimized for Touschek

Coulomb particles hitting the pipe: full geometry before tracking

HER

IR within 15 m

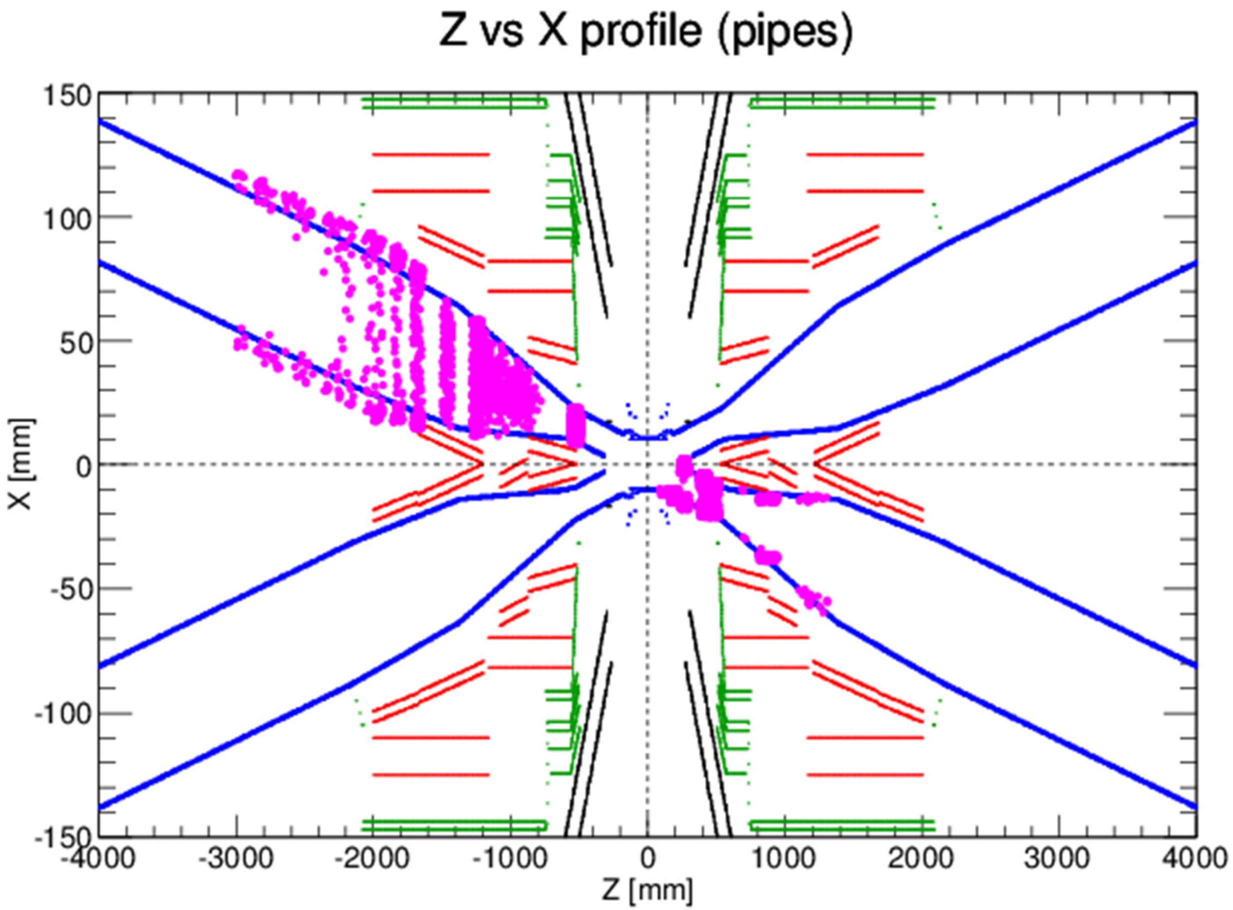


[A. Perez]

Coulomb particles hitting the pipe: full geometry before tracking

HER

Zoom: IR within 4 m



[A. Perez]

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

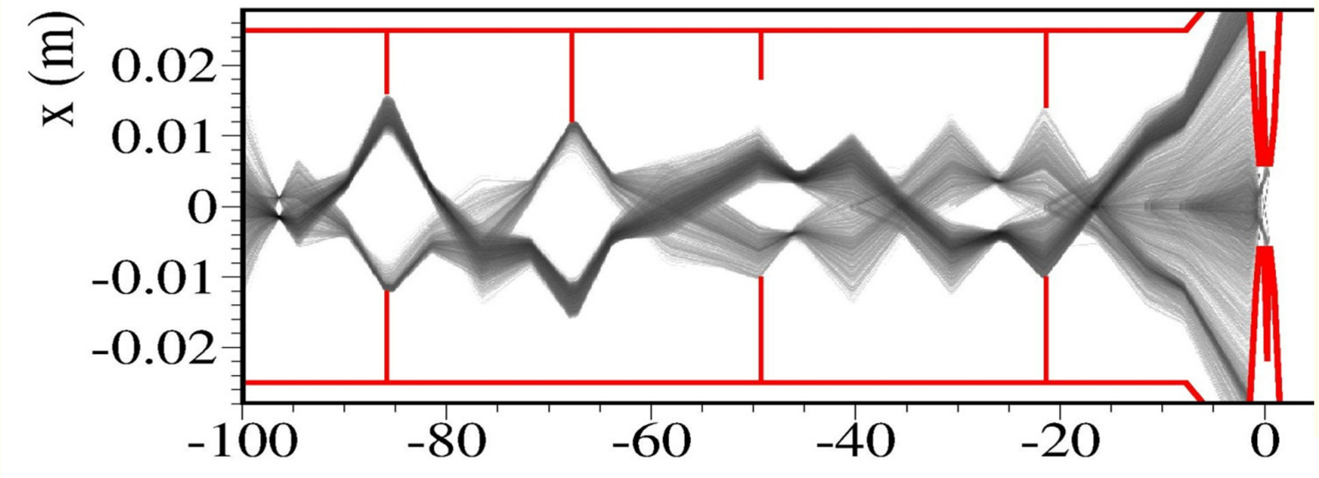
Collimator set: (mm)

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

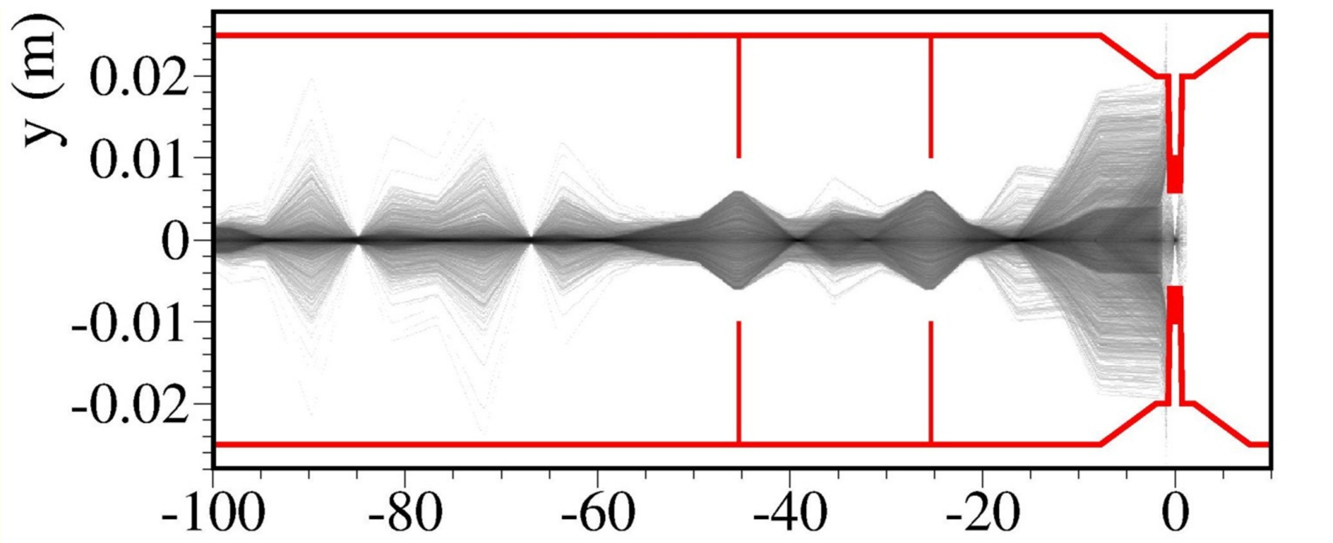
There is margin of further IR rate reduction,
As for the HER, Vcol set may be re-checked if secondaries not satisfactory (we still have margin in lifetime)

Coulomb scattered particles lost at IR

Trajectories of scattered particles eventually lost at IR



horizontal



vertical

s(m)

Lifetime summary

	HER	LER
Touschek lifetime	τ_{TOU} (min)	τ_{TOU} (min)
No collimators, nominal ε_x (no IBS)	26	7.4
No collimators, ε_x with IBS	26	10.2
With Collimators, ε_x with IBS	22	7

Coulomb	50 min	39 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**
Bremsstrahlung with coll	130KHz	450KHz

Comparison with superKEKB

	superkekb	superb
Touschek lifetime	τ_{TOU} (min)	τ_{TOU} (min)
LER Touschek no collim.	10	10.2
LER With Collimators, ε_x with IBS		7

LER Coulomb	37 min	39 min
HER Coulomb	54 min	50 min

Conclusions

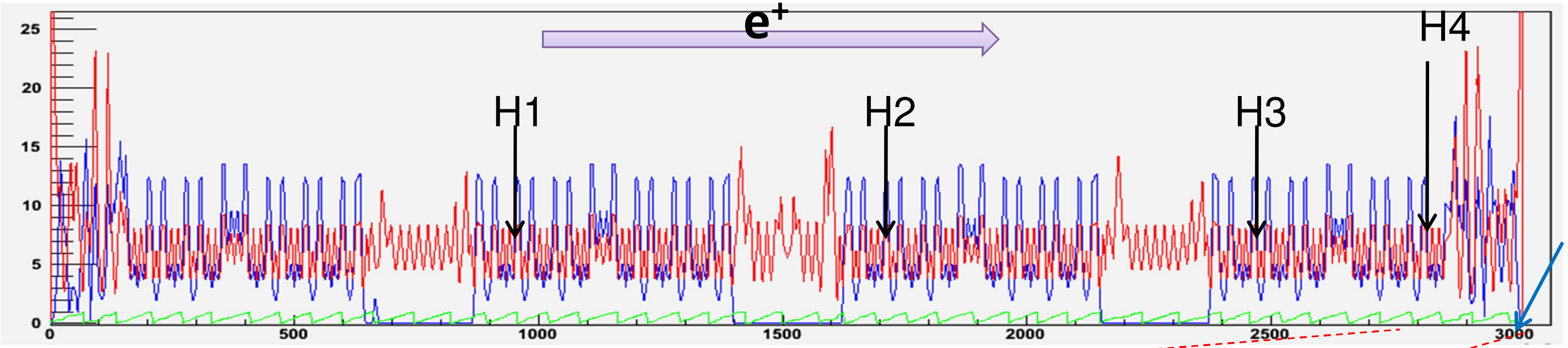
- Monte Carlo for Touschek lifetime and backgrounds is a solid simulation tool
- Background rates at IR are under control with an efficient Horiz & vert. Collimation system in the Final Focus
- More beam-gas simulation studies under variable pressure along ring are on the way
- Technical Design of realistic collimators is planned

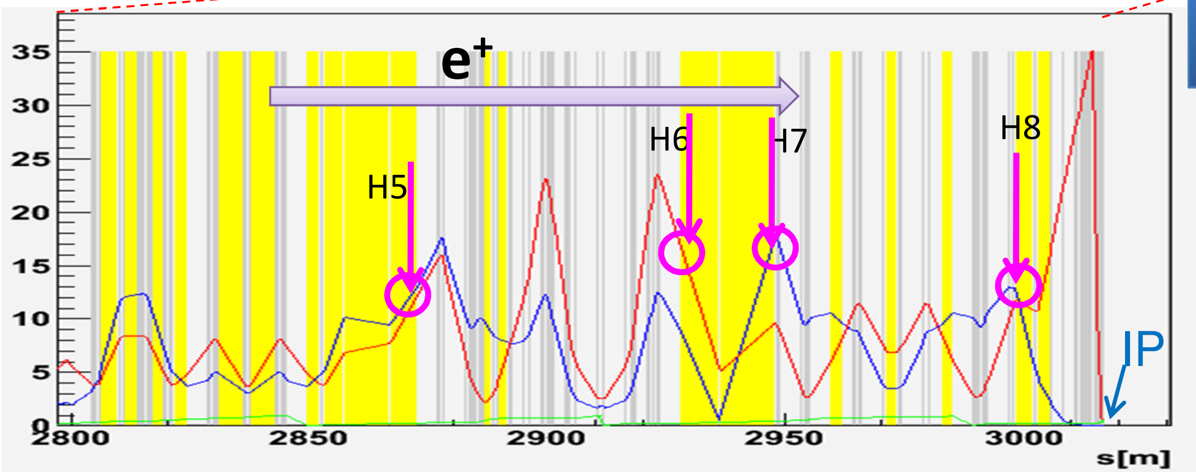
Back-up

Estimation status of each BG

- **Touschek BG**
  - Reduced down to ~0.2GHz(LER/HER) thanks to horizontal/vertical collimators (Apr. 2011)
- **Beam-gas BG**
  - Reduced down to ~0.1GHz(LER/HER) thanks to vertical collimators. (Nov. 2011)
- **Synchrotron BG**
  - Reduced down to few order smaller than PXD requirement thanks to collimation on incoming beam pipe (Jul. 2010, toy study) Full detector simulation has just started. . (Jan. 2012)
- **Radiative Bhabha**
  - Most of spent electrons/positrons are lost outside detector thanks to independent final Q magnet (Aug. 2010). But few GHz are still lost in |s|<4m (Nov. 2011).
- **2-photon process**
  - Small enough according to KoralW simulation, which is confirmed with BELLE-I machine study (Nov. 2010).
- (Beam-beam)
  - Computational study ongoing by accelerator group

LER horizontal collimators





β_x or η_x converted to collimator width (mm)

Collimator width: 10~15mm

$$d_x = Max[d_{x\beta}, d_{x\eta}, d'_{x\beta}]$$

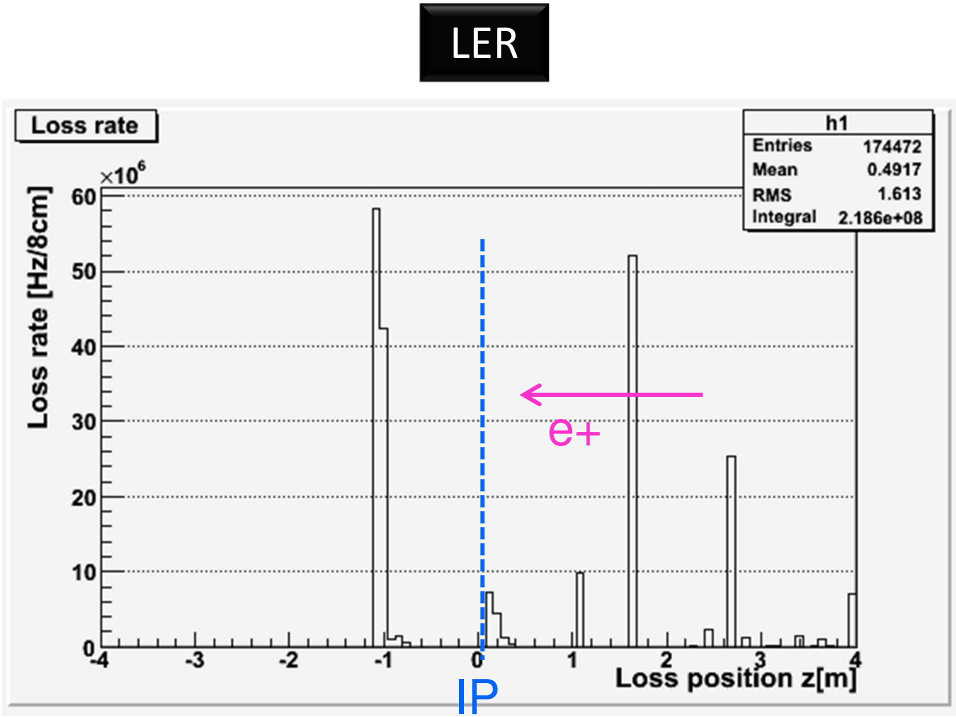
$$d_{x\beta} = n_x\sqrt{\varepsilon_x\beta_x}$$

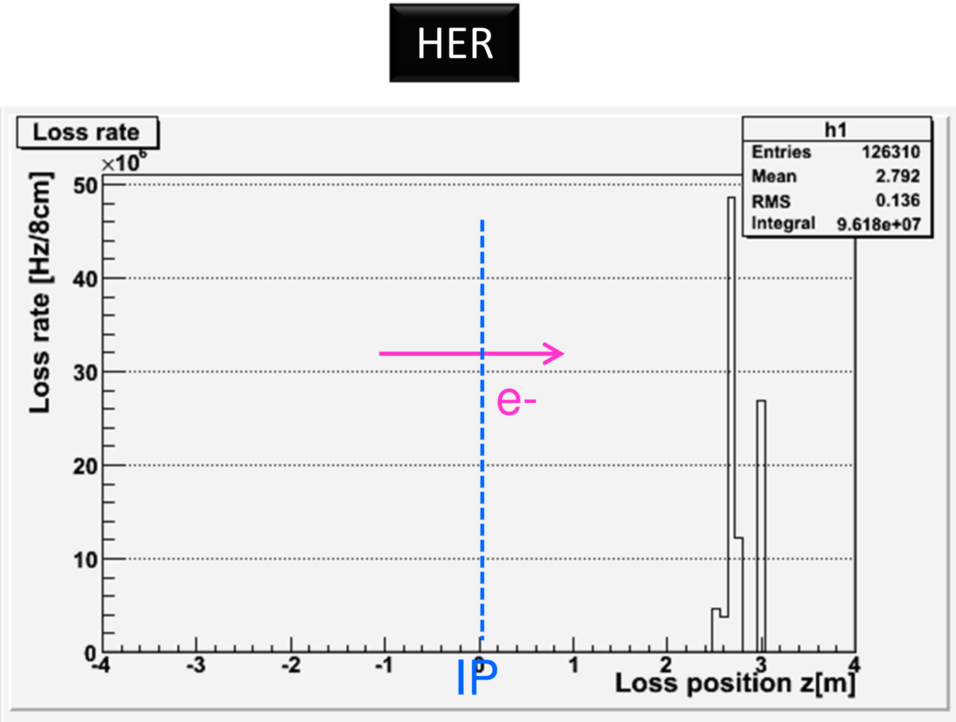
$$d_{x\eta} = \eta_x(n_z\sigma_\delta)$$

$$d'_{x\beta} = \sqrt{\frac{\beta_{x,\mathrm{mask}}}{\beta_{x,\mathrm{QC2}}}}r_{\mathrm{QC2}}$$

Compared to KEKB, we add more collimators (H5-H8) just before IP (-200m~-18m).
Collimators are located where beta function or dispersion is large.

Final Touschek loss in IR

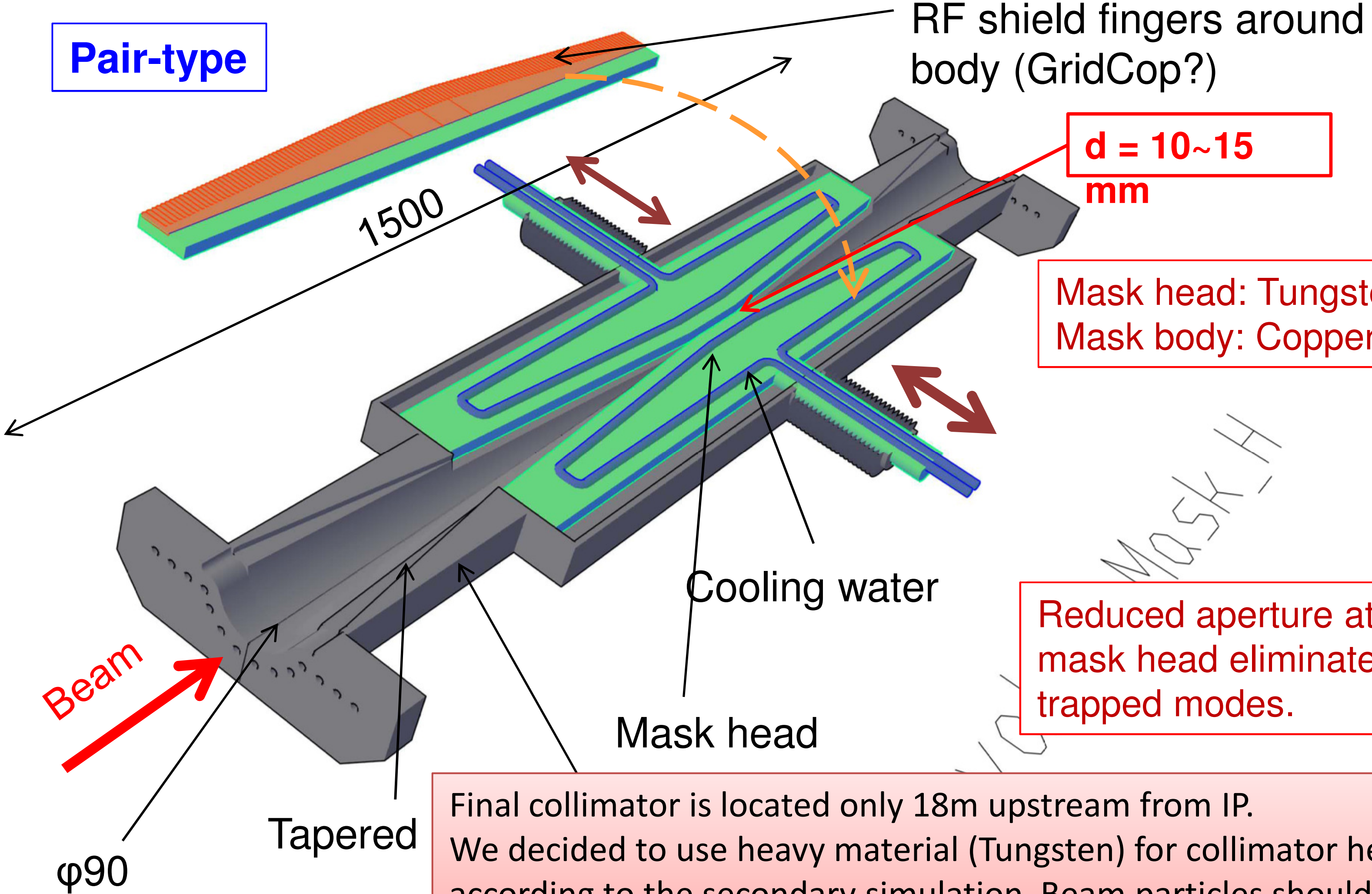




Within |z|<4m,
- loss rate: 0.22 GHz
- loss wattage: 0.14 W

Within |z|<4m,
- loss rate: 0.10 GHz
- loss wattage: 0.10 W

Concept of horizontal collimators



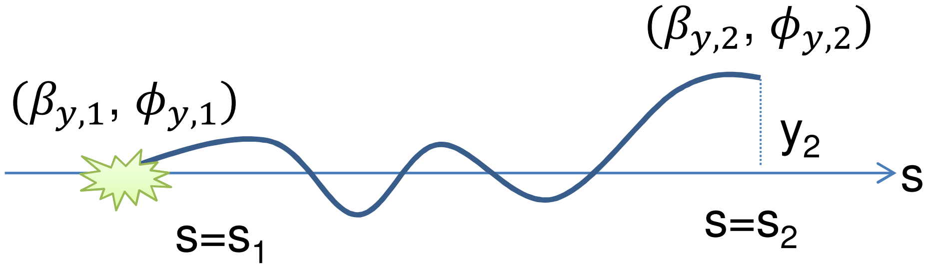
Mask head: Tungsten
Mask body: Copper

Reduced aperture at the mask head eliminates trapped modes.

Final collimator is located only 18m upstream from IP.
We decided to use heavy material (Tungsten) for collimator head, according to the secondary simulation. Beam particles should deposit enough energy to be lost before reaching IR.

H. Nakano
K. Kanazawa

Beam-gas Coulomb lifetime



θ: Scattering angle

$$y_2 = \theta \sqrt{\beta_{y,1} \cdot \beta_{y,2}} \sin(\phi_{y,2} - \phi_{y,1})$$

The minimum scattering angle θ_c to hit QC1 beam pipe

$$\theta_c = r_{QC1} / \sqrt{\langle \beta_y \rangle \cdot \beta_{y,QC1}}$$

Beam lifetime τ_R is proportional to $\theta_c^{\ 2}$

$$\frac{1}{\tau_R} = c n_G \langle \sigma_R \rangle = c n_G \frac{4\pi \sum Z^2 r_e^{\ 2}}{\gamma^2} \left\langle \frac{1}{\theta_c^{\ 2}} \right\rangle$$

	KEKB LER	SuperKEKB LER
QC1 beam pipe radius: r_{QC1}	35mm	13.5mm
Max. vertical beta (in QC1): $\beta_{y,QC1}$	600m	2900m
Averaged vertical beta: $\langle\beta_y\rangle$	23m	48m
Min. scattering angle: θ_c	0.3mrad	0.036mrad
Beam-gas Coulomb lifetime	>10 hours	2200sec

Rate $\propto$ P x I x $\langle\beta\rangle$ x β_{QC1} / $r_{QC1}^{\ 2}$

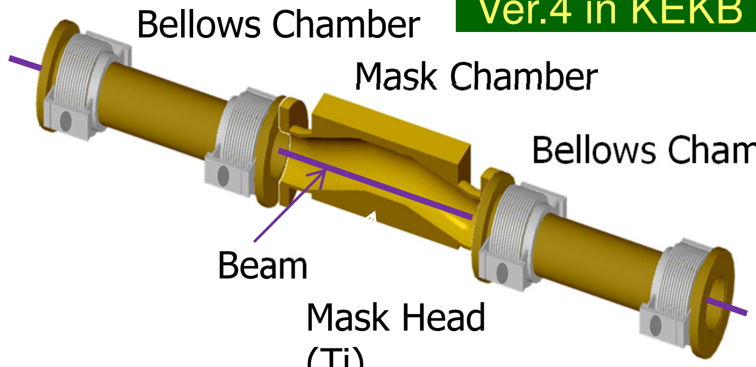
Beam-gas lifetime is only x1/100 of KEKB, due to larger vertical beta in QC1 and narrower QC1 physical aperture

Beam-gas summary

- Coulomb >> bremsstrahlung
- Larger $<\beta_y>$ and narrower IR aperture make Coulomb BG much severer at SuperKEKB than at KEKB
- Vertical collimators , placed at small beta_y, can reduce beam-gas BG down to ~0.1GHz for LER/HER.
- Beam instability for such collimators is confirmed to be tolerable, performing tracking simulation with realistic collimator shape
- Vacuum level at large beta_y affects beam-gas lifetime.
- Simulation using "SAD" is in preparation
- R&D ongoing for collimator which can resist ~100GHz loss

Design of key components_11

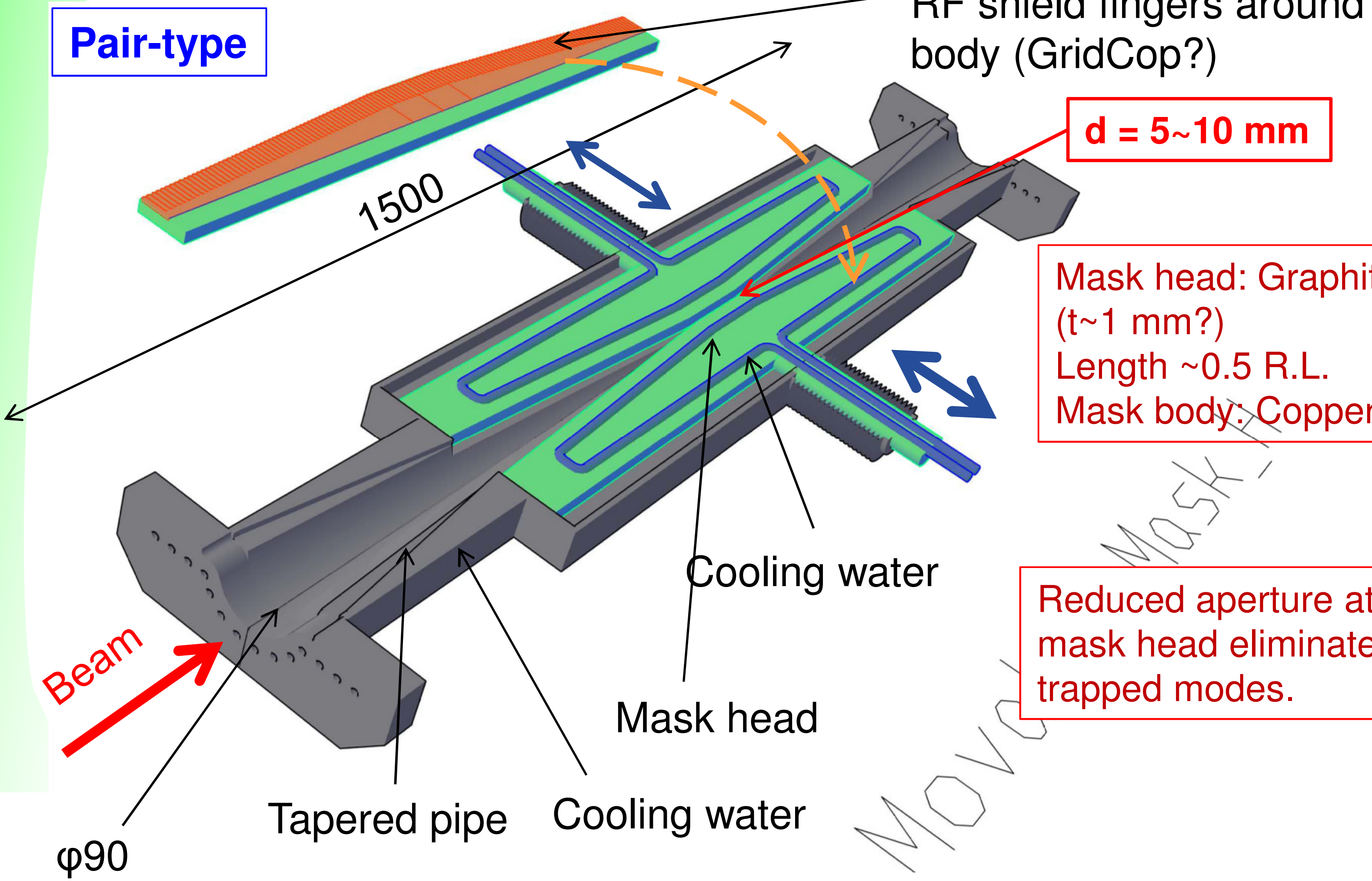
- **Movable mask (collimator)**
  - Indispensable in order to reduce background noise of BELL-II
  - Long R&D history in KEKB
    - Stealth type was proposed, but not yet realized.
  - **For SKEKB,**
    - High thermal strength against wall heating (~ 1 mm from beam for vertical type)
    - Low beam impedance (ex. Against TMC instability)
    - Fitting to antechamber scheme
    - Robust against impact of beam in case
    - Placed at both sides of the ring
    - HOM absorbers (near to masks)
  - Concept of Ver.4 in KEKB will be available, at least in the beginning stage: how to fit to antechamber scheme?



⇨ **One candidate: PEP-II type**

Design of key components_13

- Concept of **horizontal** movable mask



Mask head: Graphite?
(t~1 mm?)
Length ~0.5 R.L.
Mask body: Copper

Reduced aperture at the mask head eliminates trapped modes.

Design of key components_14

- **Concept of vertical movable mask**