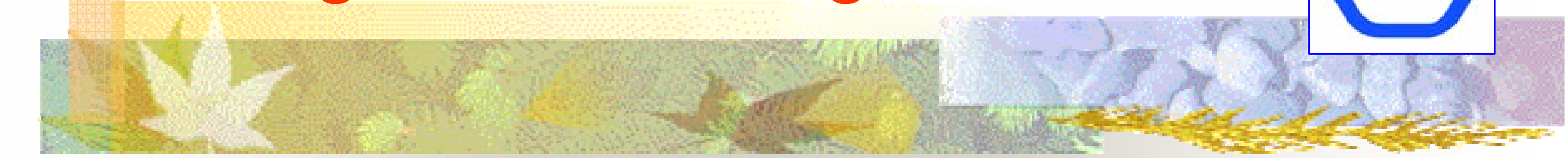
INFN
Istituto Nazionale
di Fisica Nucleare

Single beam backgrounds



Manuela Boscolo

SuperB Workshop, Orsay, Febr. 16th 2009

Dominant effects on backgrounds and lifetime

Two colliding beams

- **Radiative Bhabha** → dominant effect on lifetime
- **Pairs Production** → only ~ 3% contribution to rad. bhabha lifetime but important source of background in SVT

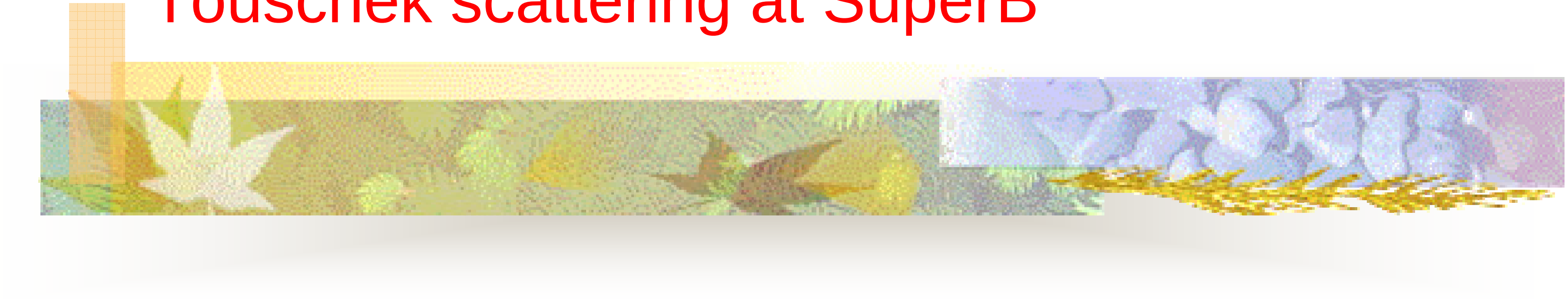
Single beam

- **Synchrotron Radiation** -strictly connected to IR design
- **Touschek** → update on a large statistics (a factor 100 increase) with the June08 lattice, and on new tracking with Jan09 LER lattice
- **Beam-gas** → Developed a simulation code with MC technique, first evaluations with June08 lattice
- **Intra-beam scattering** → an update on simulation for present lattice

Outline
Touschek background and lifetime

- **June 08 LER and HER lattice:** generated Touschek particle losses with high statistics → secondaries under analysis by background simulation group
- **Jan. 09 LER lattice -**last IR design from M. Sullivan- first results, work ongoing
- **present DAFNE crab waist lattice:** comparison with measurements
- **Development of the simulation code:** always ongoing

Touschek scattering at SuperB



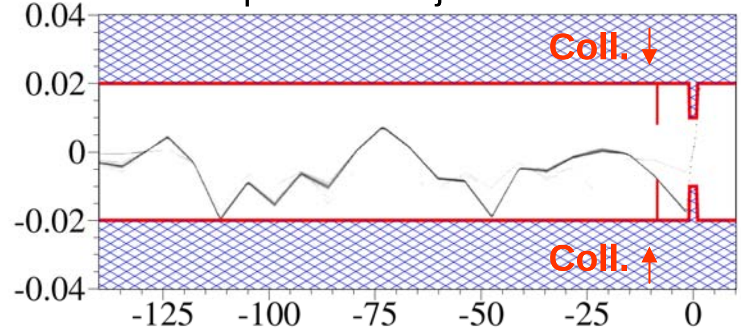
SuperB Workshop, Orsay, Febr. 16th 2009

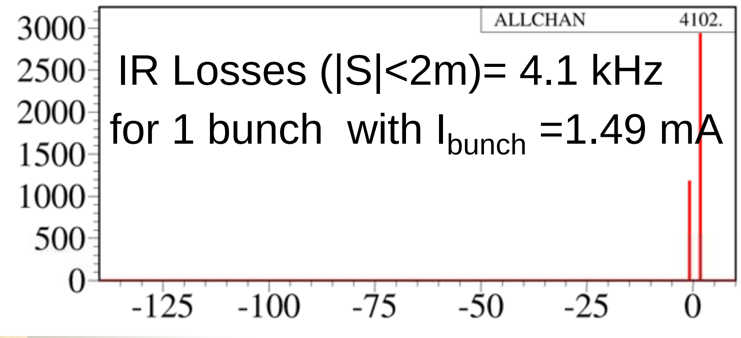
June 08 lattice

LER Touschek particles lost at IR

with IR COLLIMATOR inserted s = -8.5 m far from IP at about 20 σ_x

example of
LER Touschek particles trajectories lost at the QD0





IR Losses (|S|<2m)= 4.1 kHz
for 1 bunch with I_{bunch} =1.49 mA

UPDATE : 100 more statistics

Touschek lifetime ≈ 20 min

(results given at the Elba worshop confirmed)

both for LER and HER:

These particle losses close to QD0 will be fully simulated into the detector by background simulation group

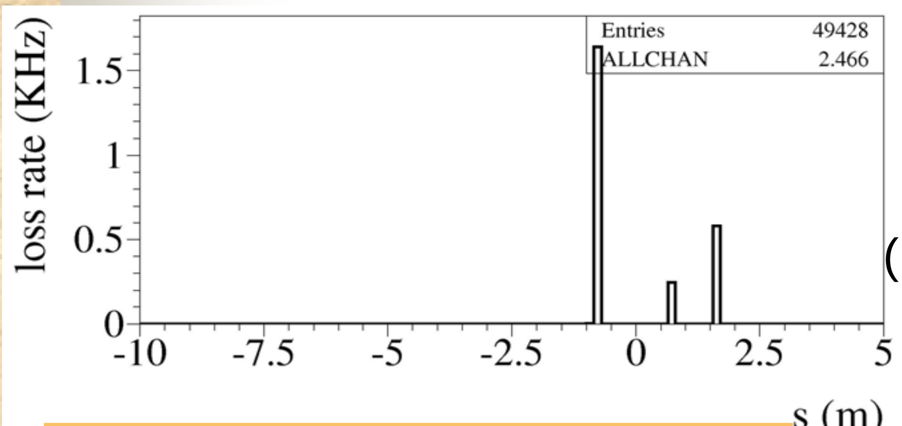
IR collimator modeled as perfectly absorbing and no width.

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

IR Losses (|S|<2m)= 5.1 MHz
at full current

June 08 lattice

HER Touschek particles lost at IR
with IR COLLIMATOR inserted S=-8.5 m far from IP at about 20 σ_x

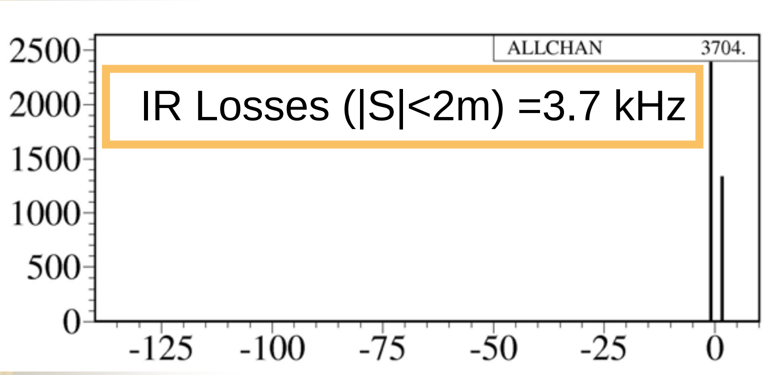


UPDATE: 100 more statistics

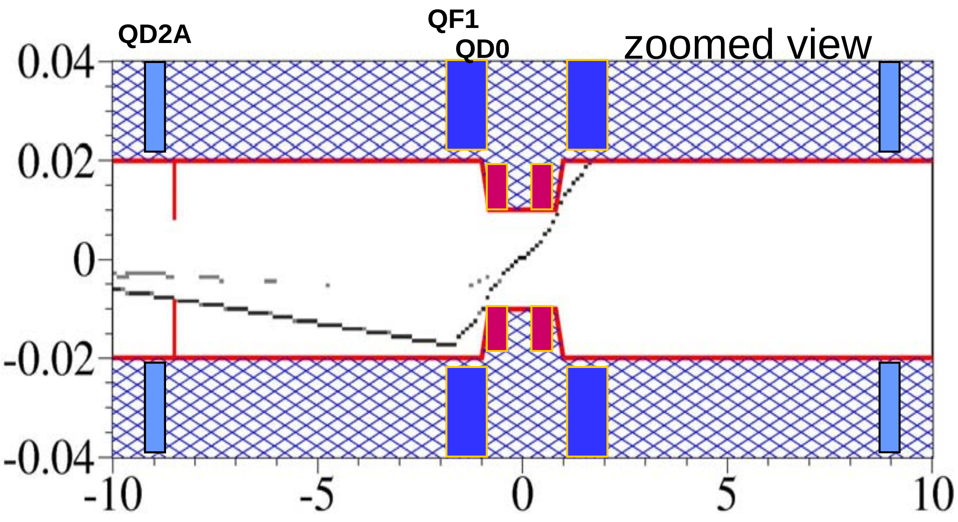
Touschek lifetime ≈ 32 min

(results given at the Elba worshop confirmed)

IR Losses (|S|<2m) = 2.5 kHz
for 1 bunch with I_{bunch} =1.49 mA



IR Losses (|S|<2m) =3.7 kHz

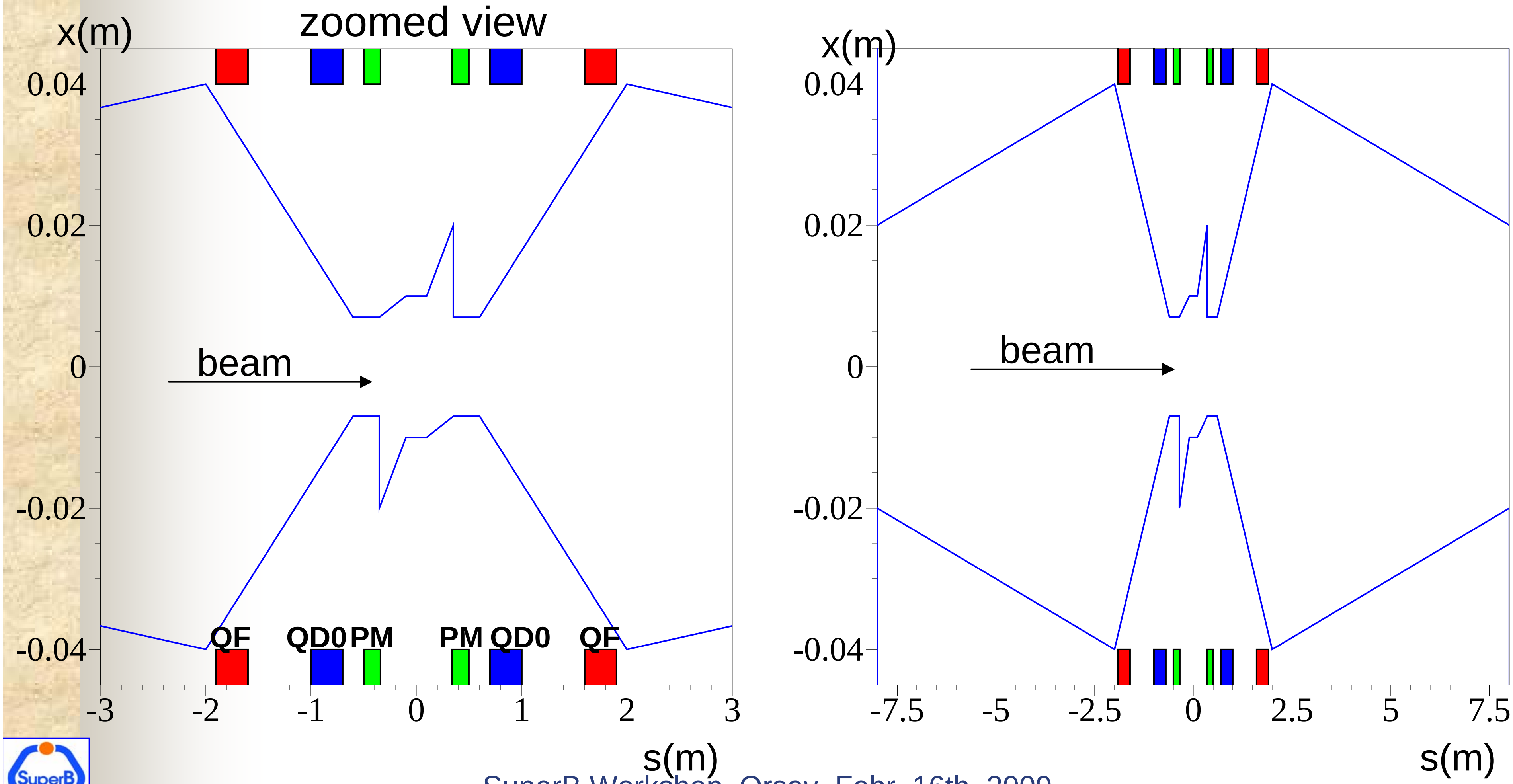


zoomed view

Jan. 09 LER Lattice:

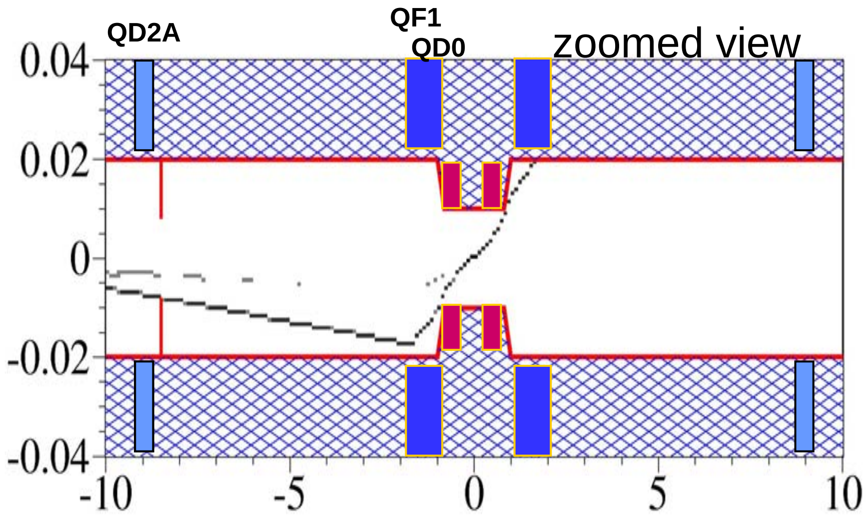
New IR from M. Sullivan

implemented new **horizontal physical aperture**



Update Touschek simulation – physical aperture

- there was **cylindrical** beam pipe with R = 2cm except for IR: 1cm at QD0



- now **elliptic** beam pipe – update ongoing:

vertical aperture 2 cm everywhere, it will be variable in the IR according to design

horizontal size at IR varies according to last design

Program Flow Touschek simulation

Optics check

(nonlinearities included)

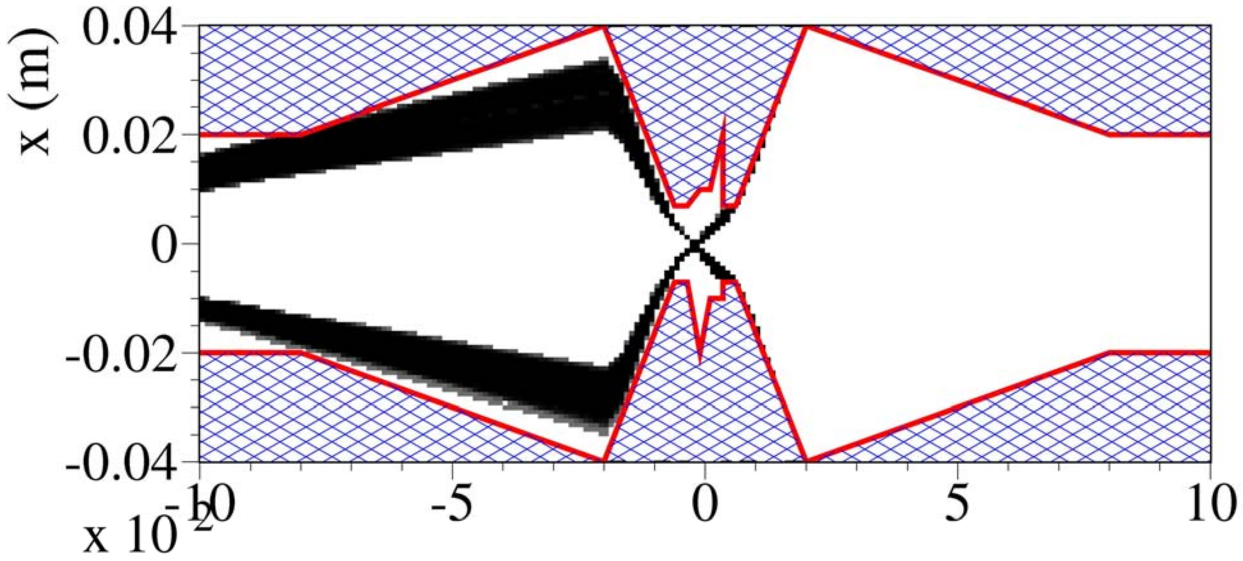
Beam parameters calculation
(betatron tunes, emittance, synchrotron integrals, natural energy spread, bunch dimensions, optical functions and Twiss parameters all along the ring)

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

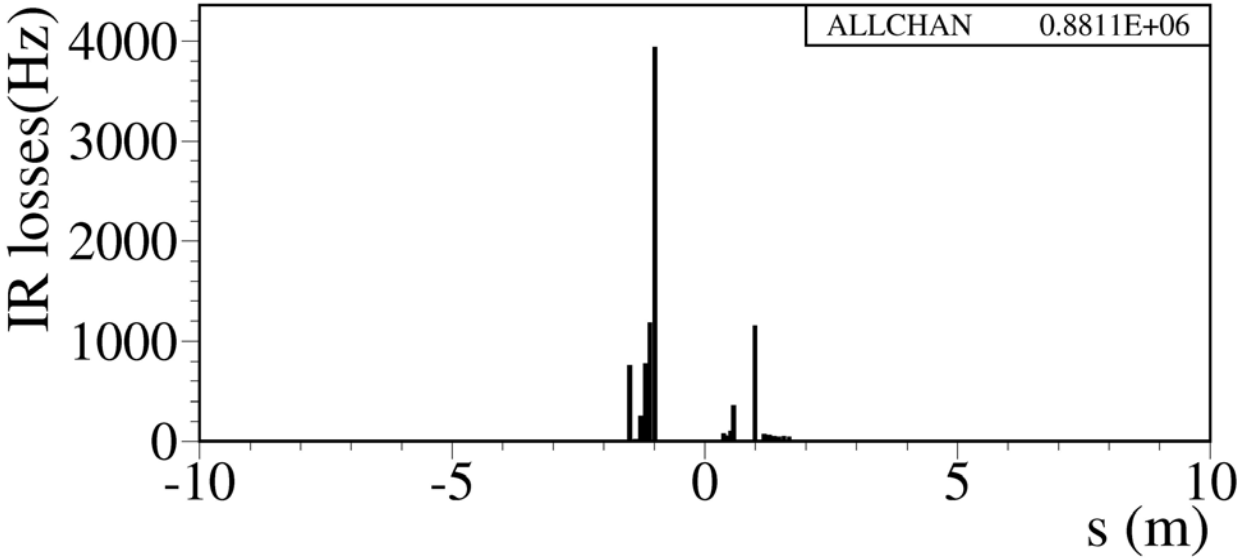
Tracking of Touschek particles:
Start with transverse gaussian distribution and proper energy spectra every 3 elements: track over many turns or until they are lost
Physical aperture assumed elliptical and variable along s both in x and y

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

LER – Jan.09 lattice – First results



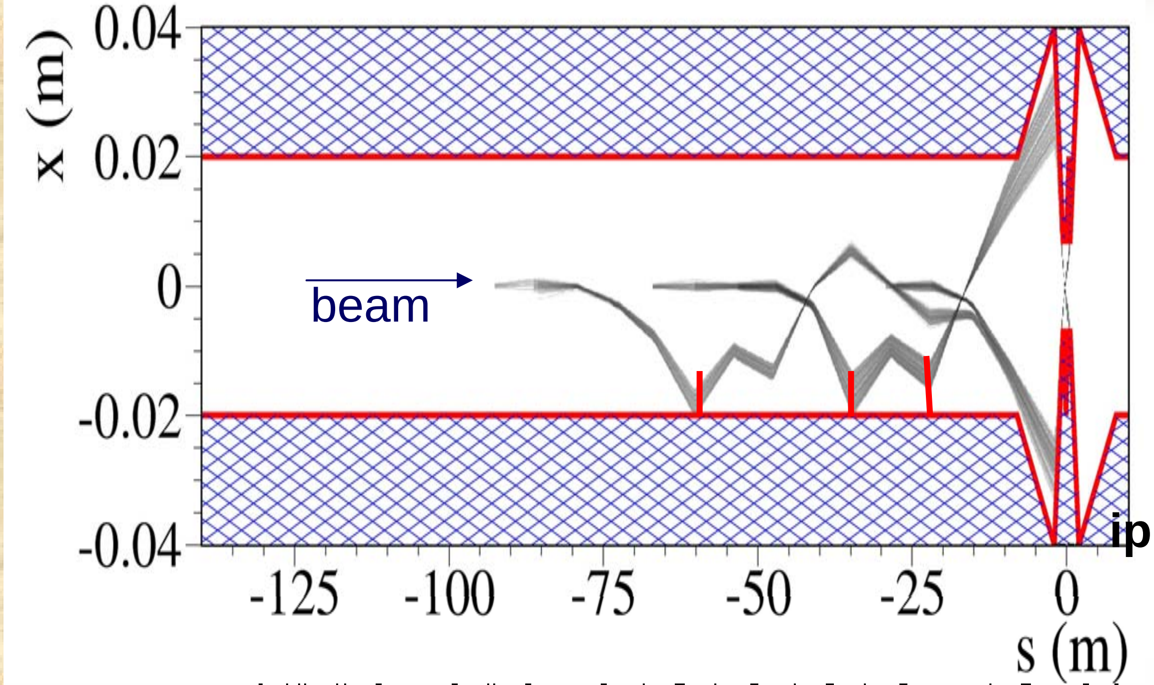
IR particle trajectories

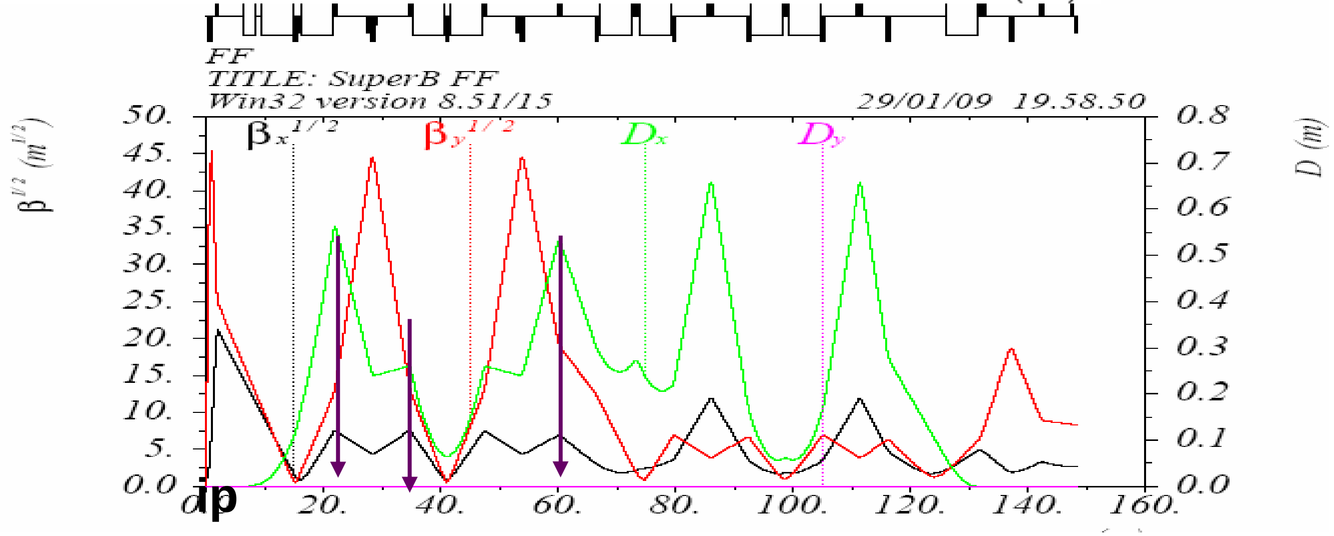


IR particle losses

COLLIMATORS LER – Jan.09 lattice

Touschek particles that get lost at IR





suitable positions at high dispersion and low β_x:

at ≅ 20 m, 37 m and 60 m upstream IP

LER Energy acceptance

1 machine turn

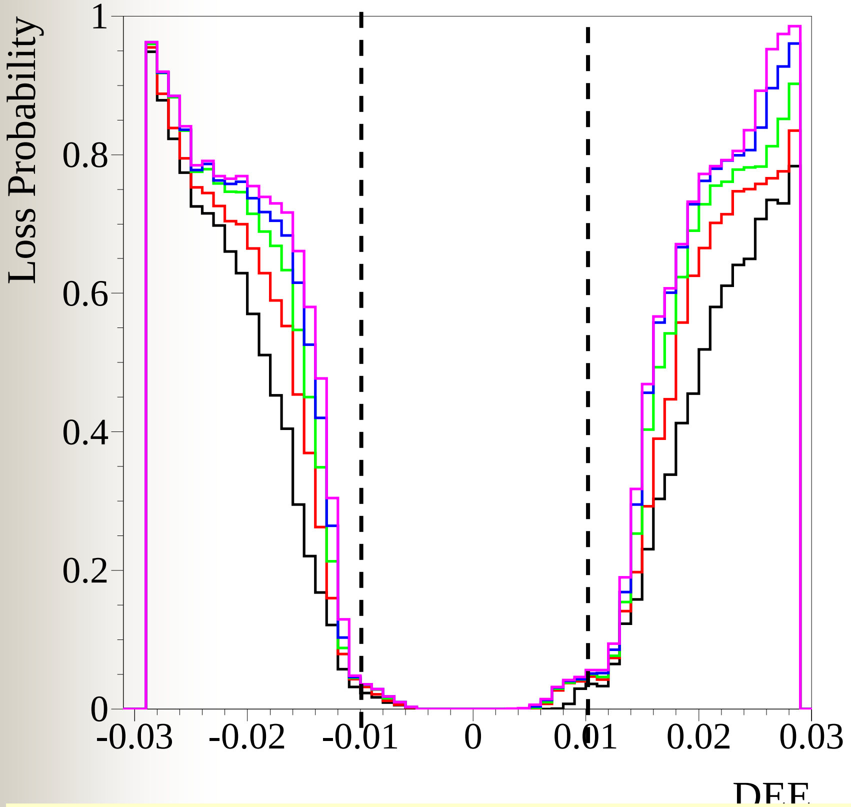
2 machine turns

3 machine turns

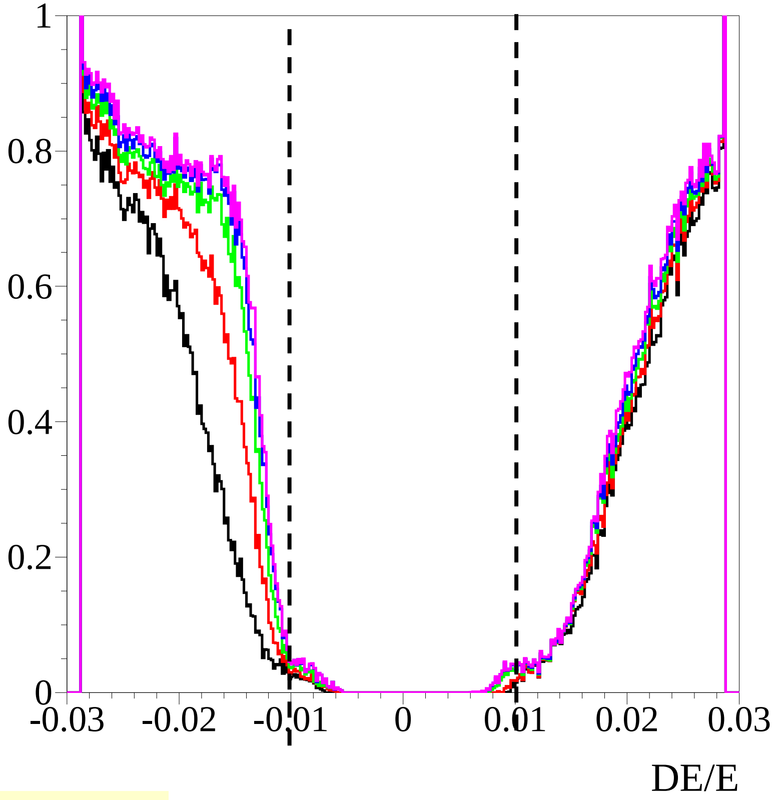
4 machine turns

5 machine turns

Jan.09 lattice



June08 lattice



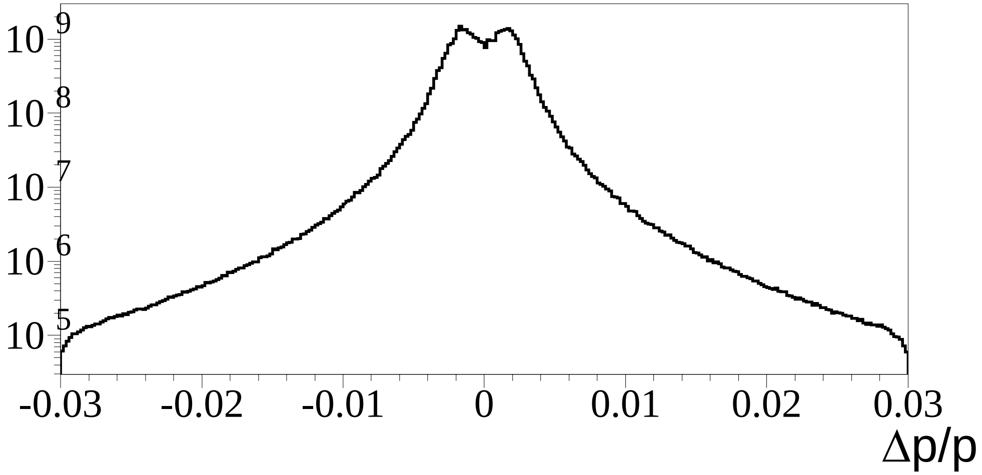
Energy acceptance is lower, (especially at DE/E>0)

As expected – no optimization on DA for off.energy part. has been done yet

lower lifetime predicted

SuperB: Comparison between lifetime estimate from formula and calculation from tracking (CDR lattice)

generated Touschek particles per second all over the ring



Reference:

τ(CDR)=330 s (Wienands)

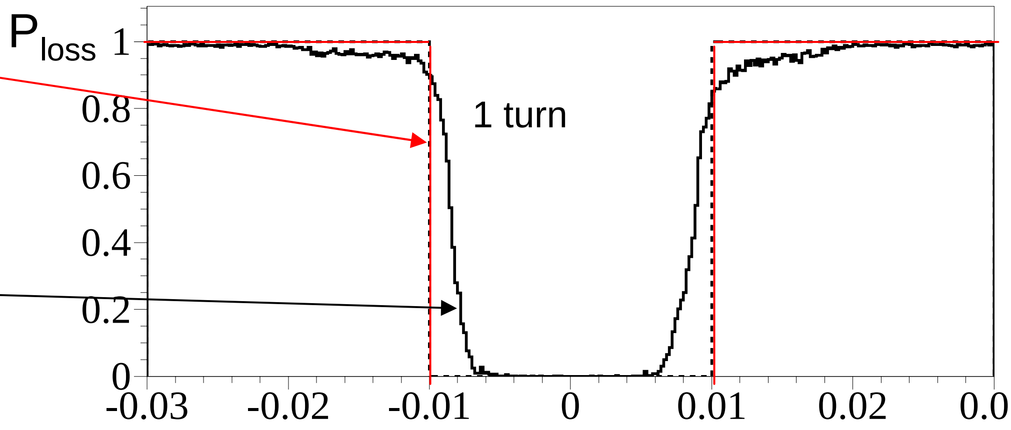
assuming that particles with |Δp/p|>1% are lost (like CDR):

τ = 308 s

good agreement with CDR

efficiency calculated from tracking

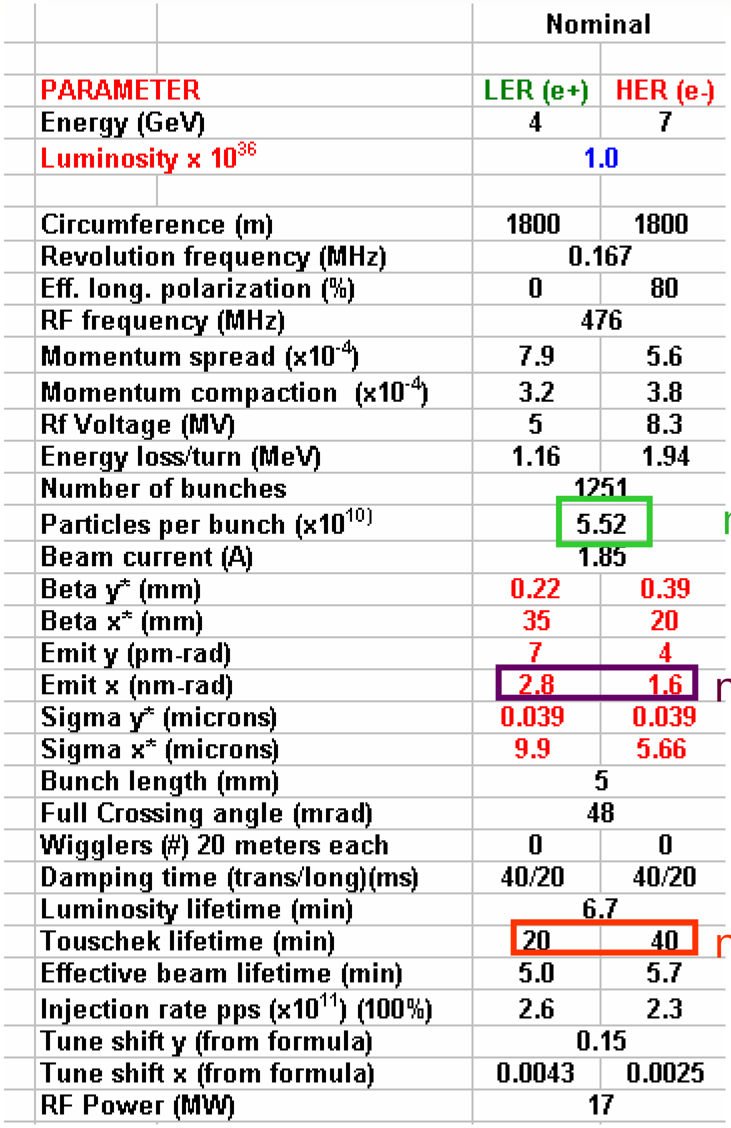
τ = 200 s



tracked particles with Δp/p= 0.6%-0.8% are lost, with some efficiency. These have very large weight, this induces difference in lifetime estimation

(Touschek function very non linear)

SuperB Parameters (June 2008)



	Nominal	
PARAMETER	LER (e+)	HER (e-)
Energy (GeV)	4	7
Luminosity x 10^{36}	1.0	
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
Momentum compaction (x10^{-4})	3.2	3.8
Rf Voltage (MV)	5	8.3
Energy loss/turn (MeV)	1.16	1.94
Number of bunches	1251	
Particles per bunch (x10^{10})	5.52	
Beam current (A)	1.85	
Beta y* (mm)	0.22	0.39
Beta x* (mm)	35	20
Emit y (pm-rad)	7	4
Emit x (nm-rad)	2.8	1.6
Sigma y* (microns)	0.039	0.039
Sigma x* (microns)	9.9	5.66
Bunch length (mm)	5	
Full Crossing angle (mrad)	48	
Wigglers (#) 20 meters each	0	0
Damping time (trans/long)(ms)	40/20	40/20
Luminosity lifetime (min)	6.7	
Touschek lifetime (min)	20	40
Effective beam lifetime (min)	5.0	5.7
Injection rate pps (x10^{11}) (100%)	2.6	2.3
Tune shift y (from formula)	0.15	
Tune shift x (from formula)	0.0043	0.0025
RF Power (MW)	17	

nominal CDR lattice:

now N_b slightly lower
(LER/HER 6.16/3.52)

now higher LER horiz. emitt.
(LER/ HER 1.6/1.6)

now higher Tou. lifetime
(LER/ HER 3.6/5.1)

Touschek lifetime estimates

coupling = 0.25%

LER Lattice	Touschek lifetime (min)
June 08 (only sextup.) optimized DA Cylindrical phys. aperture	24
Jan. 09 (only sextup.) **NON** optimized DA Elliptic phys. aperture at IR	16

very preliminary!

work still in progress both in the lattice (DA for off-energy part.) and bkg/lifetime simulations

of course an enlargement of emittance due to IBS of the order of 10-15% (see S. Guiducci's talk), if not corrected, would increase Touschek lifetime accordingly

SCALING of Touschek loss rate dN/dt and lifetime τ with beam parameters

$$\frac{1}{\tau} = \frac{1}{N}\frac{dN}{dt}$$

The Touschek part. loss rate is approximately

$$\dot{N} \propto \frac{N^2}{\gamma^3 \varepsilon^2 V}$$

N particles/bunch

V bunch volume

ε momentum acceptance

Touschek effect is determined by momentum acceptance and bunch density integrated over the lattice structure.

Lifetime $$\tau \propto \frac{\sigma_x \sigma_y \sigma_z}{I}$$

where $$\sigma_z \propto I^{1/3}$$

$$\tau \propto I^{-2/3}$$

$$dN/dt \propto I/\tau \propto I^{5/3}$$

$$\frac{dN}{dt} \propto 1/\sqrt{\kappa}$$

$$\kappa = \varepsilon_y / \varepsilon_x$$

Conclusions on
Touschek background and lifetime studies at SuperB

- Simulation studies proceed together with lattice updates
- Secondaries in detectors proceed as well, just one step behind, as it should be

- Developments on simulation code proceed as lattice and design gets more detailed and complicated

Touschek scattering at DAFNE

Background and lifetime studies

with the lattice present in machine now (Febr. 3rd 09 dataset)

with real collimators positions (only movable ones at DAFNE)

aim is to compare MC to measurements, in progress

SuperB Workshop, Orsay, Febr. 16th 2009

Backgrounds simulation

It is a very difficult task:
very rare and complex processes

many particles in colliding bunches but only few of them are lost for these processes

complex to generate and to track in detectors (detailed geometry and tracking of secondary)

hard to predict what detectors will see

Approximations in single beam background simulation

- Approximations in calculating a particular background process
- Approximations in deciding which are the dominant processes

Comparison with actual experience

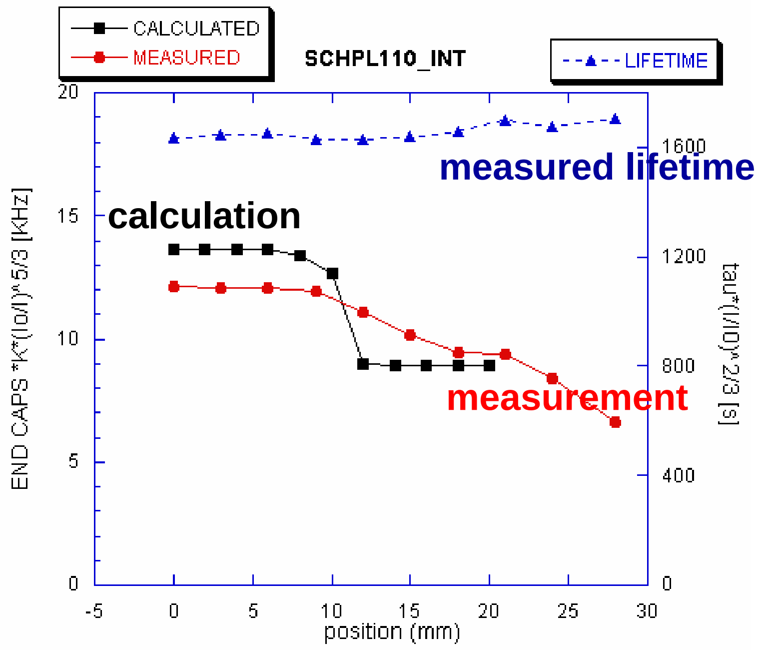
It is valuable and possibly essential for a successful design to compare our calculational techniques and procedures with data from a real detector at a real storage ring

Acceptable agreement does not assure success, of course, because scaling from one machine to another is not so direct…but it would be a good start.

Comparison between measured and calculated effectiveness of collimators

The calculated rate is evaluated by tracking Touschek scattered particles from their loss point in the pipe into the KLOE detector. The endcap acceptance has been taken into account by means of full detector simulation including the geometrical details of the IR.

The MC reproduces behaviour of background vs collimator position
absolute normalization



Scan of the background rate in the KLOE forward calorimeter versus position of the internal jaw of a collimator: The collimator opening is measured from the beam pipe edge.

DAFNE Detectors Sensitivity to Backgrounds

- KLOE suffered from ‘high’ energy particles (E> 10 MeV) –
  seen in overlap with physics (accidentals)

  also important higher energy products with E>150MeV (endcap trigger threshold)

  4π acceptance- difficult shielding

- DEAR suffered from low energy photons (O(100) keV)-

  no trigger, but small gas target detector could be shielded by lead all around

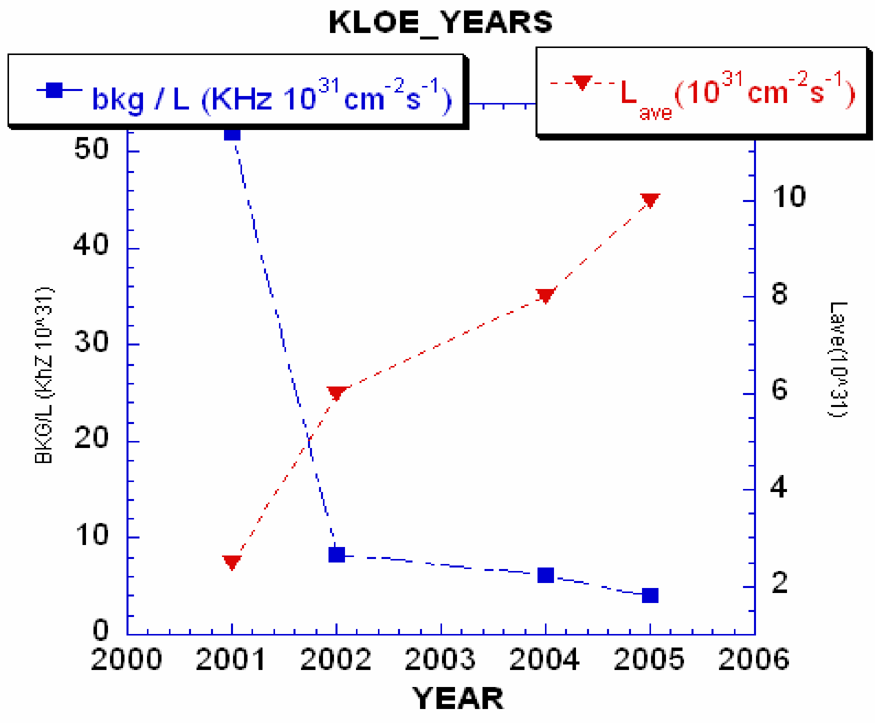
•SIDDHARTA is a gas target detector with trigger, many shieldings have been tested to optimize S/N

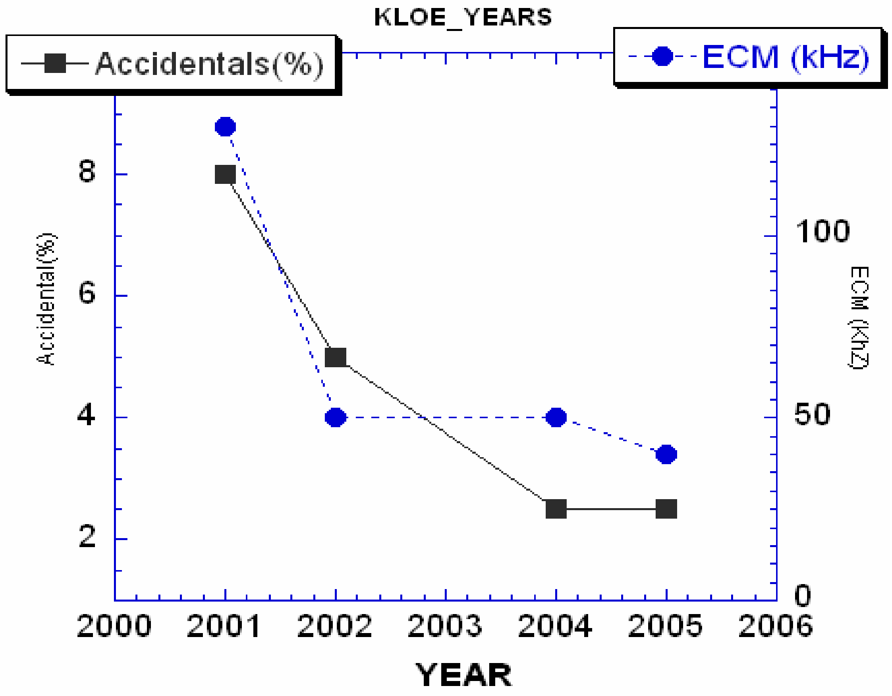
now- CRAB waist

At the beginning of data taking, all these experiments suffered from large background.

Backgrounds and Luminosity

versus years of **KLO**E data taking





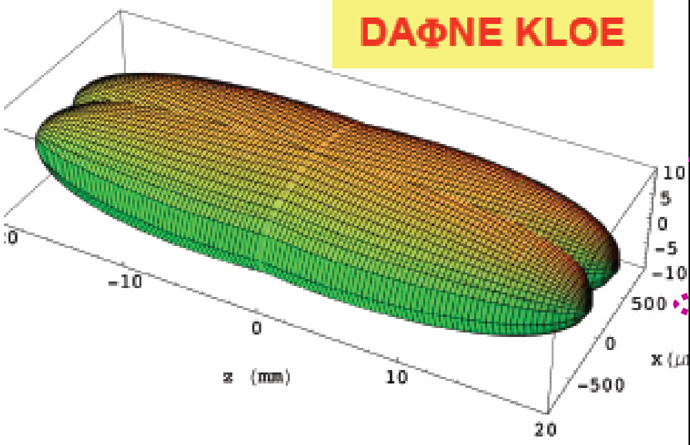
	L_{ave} (10^{31} cm^{-2}s^{-1})	Bkg_{ave} (kHz)	Bkg/L (kHz 10^{31} cm^{2}s^{1})	Accidental probability
2001	2.5	130	50	8%
2002	6	50	8.3	5%
2004	8	50	6.25	2.5%
2005	10	40	4	2.5%

Touschek Backgrounds for the Crab waist scheme at DAFNE

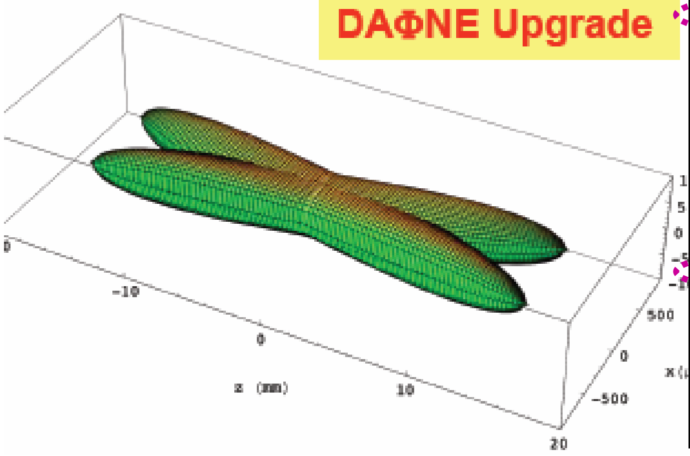
Energy deviat.	0.001 -0.04
σ_p/p	4 e-4
coupling	0.005
N_p	$2\cdot10^{10}$
I_{bunch}(mA)	10

BEAM DISTRIBUTION AT IP

DAΦNE KLOE



DAΦNE Upgrade



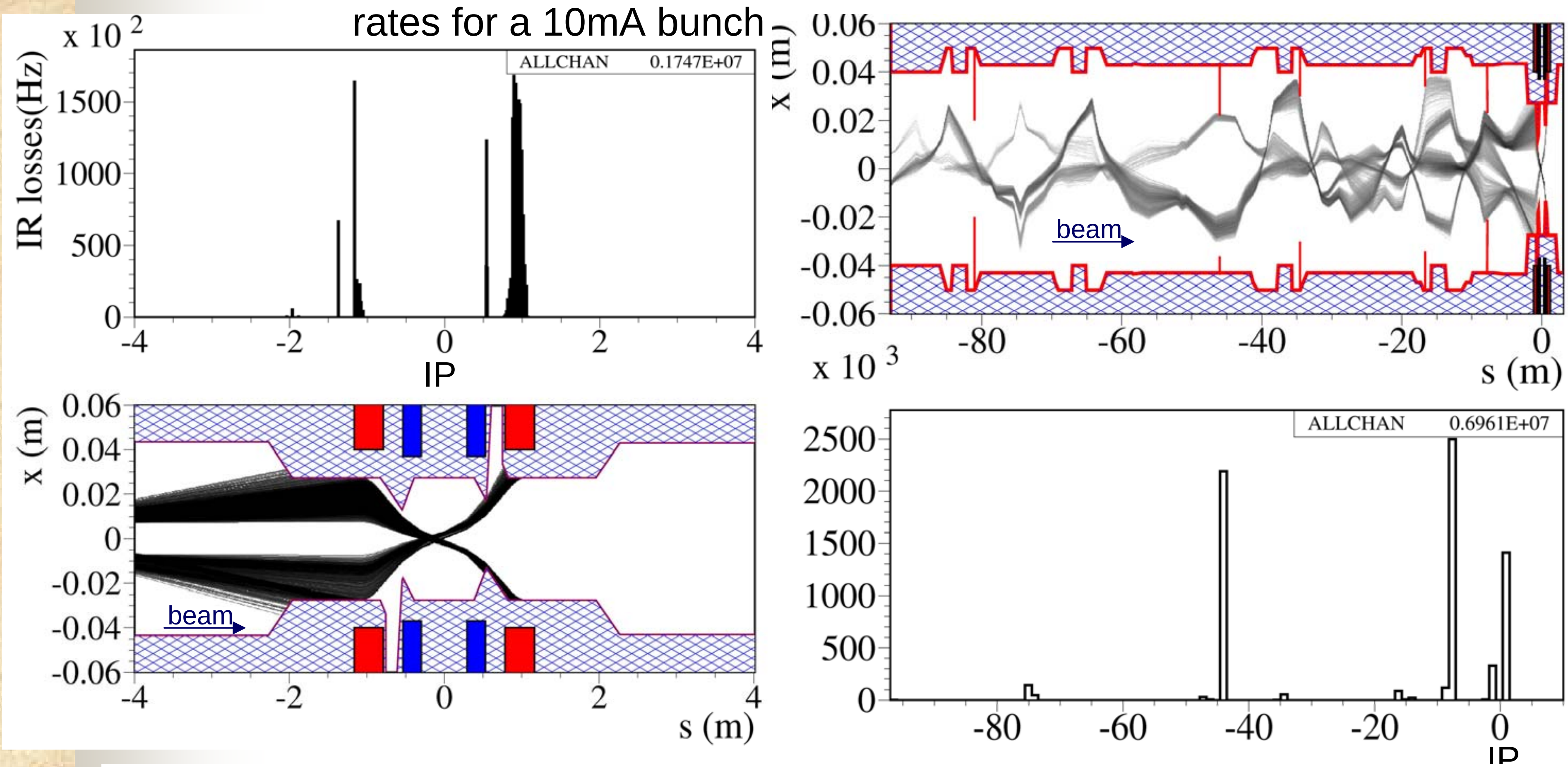
	FINUDA	Upgrade
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mmxmrad)	0.34	0.26
β_x^* (cm)	170	26
σ_x^* (mm)	0.76	0.26
$\Phi_{Piwinski}$	0.3-0.6	1.9
β_y^* (cm)	1.70	0.90
σ_y^* (μm)	5.4 (low current)	3.1
Coupling, %	0.5	0.5
I_{bunch} (mA)	13	13
σ_z (mm)	22	20
N_{bunch}	110	110
L ($cm^{-2}s^{-1}$) $x10^{32}$	1.6	5

smaller beam sizes and emittance

⇩

Touschek more important in update configuration

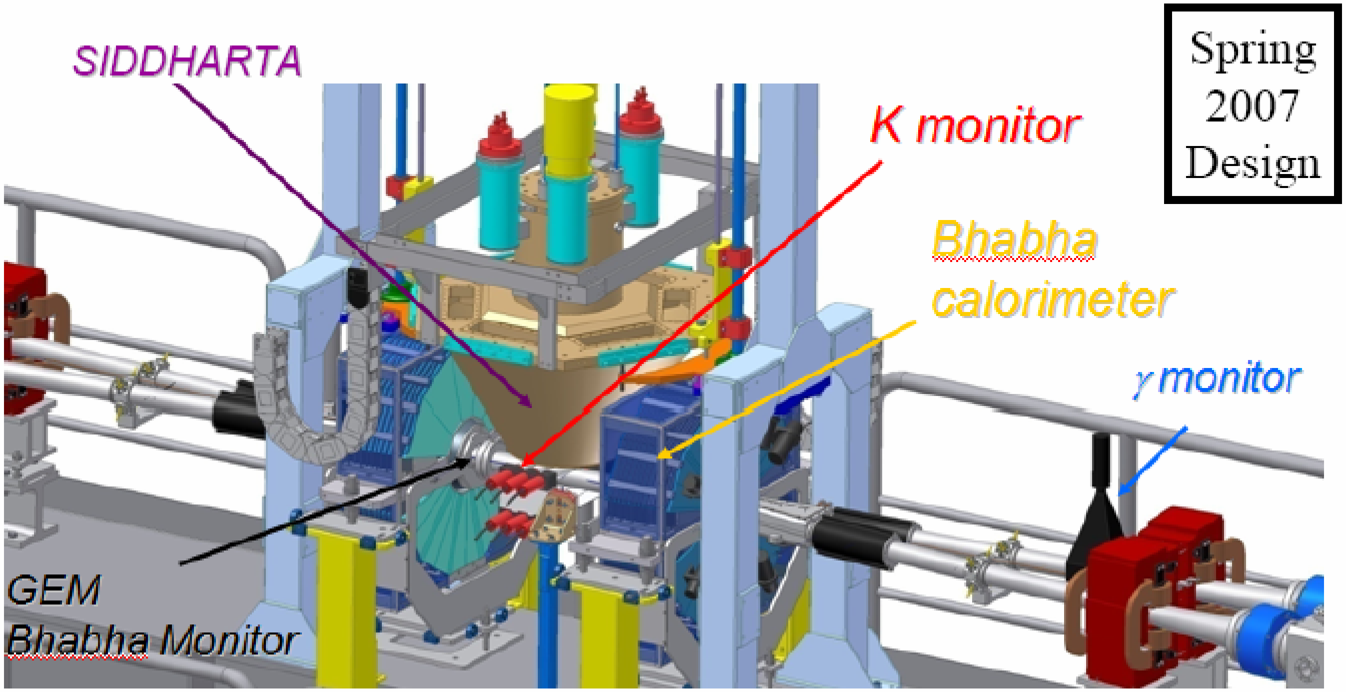
Touschek background at DAFNE with crab waist



these particles are being tracked with GEANT4 up to a Bhabha monitor in order

to compare to measurements- with lumi collaboration

DAFNE IR layout



Calorimeter is 19cm thick and starts at 32.5cm from IP

γ monitor is at 1.7m from IP

N. Arnaud’s talk for description of different detectors

Touschek lifetime at DAFNE

lifetime as short as about 600 s

Simulation predicts about 1600 s

I am investigating this discrepancy:

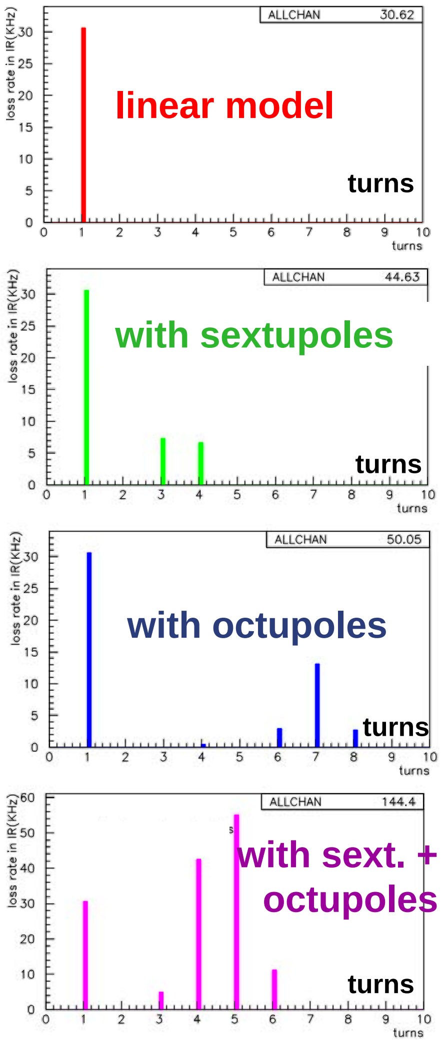
for a realistic tracking of Touschek off-energy particles ‘all’ non-linearities in magnets should be taken into account

still working on this:

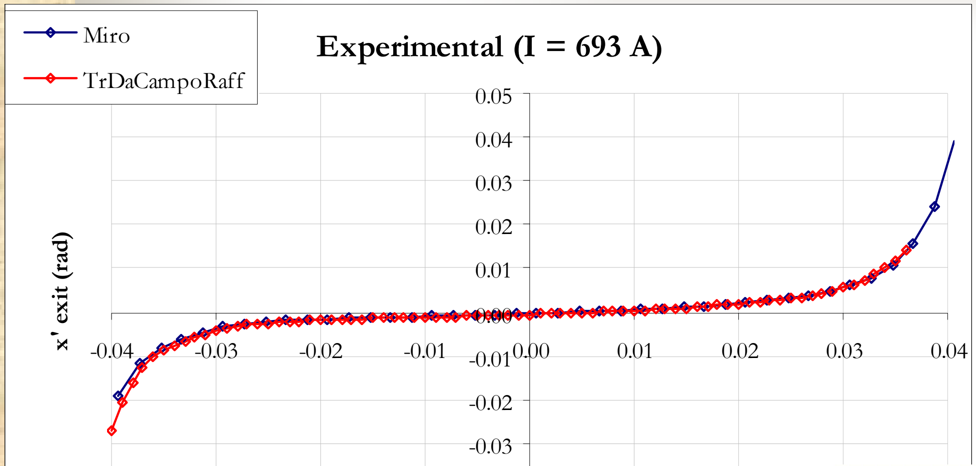
introduced a dodecapole +decapole term at center of each wiggler: lifetime shortens and IR losses increase, as expected from measurements.

For a more realistic simulation I will introduce the decapole and dodecapole terms in each wiggler pole.

Touschek particle losses vs machine turns

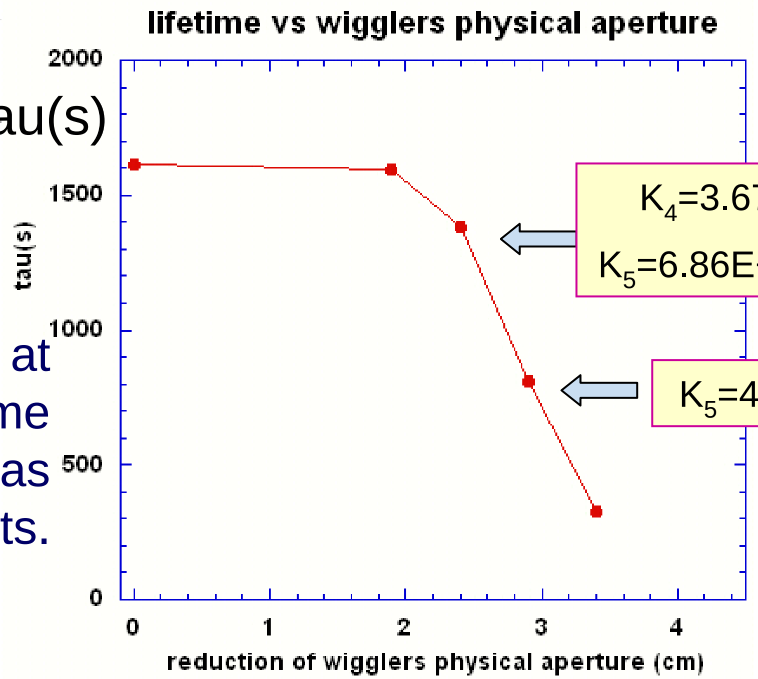


Simulation of DAFNE Touschek lifetime



S. Bettoni et al.

Multipolar analysis from wigglers experimental maps

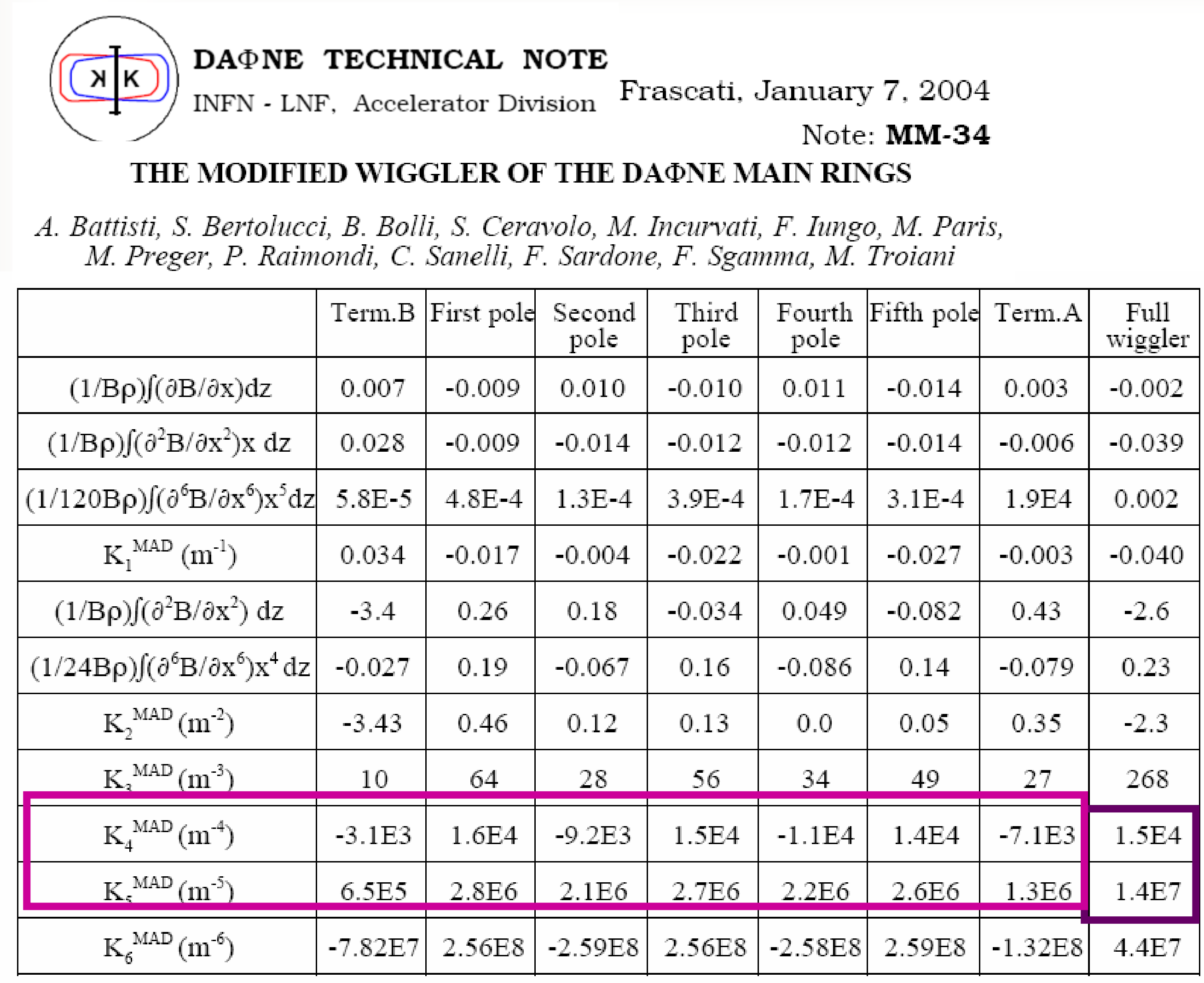


K_4=3.67E+2 (decapole)

K_5=6.86E+4 (dodecapole)

K_5=4.5E+5 (dodecapole

with the dodecapole +decapole term at center of each wiggler: lifetime shortens and IR losses increase, as expected from measurements.



DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, January 7, 2004

Note: **MM-34**

THE MODIFIED WIGGLER OF THE DAΦNE MAIN RINGS

A. Battisti, S. Bertolucci, B. Bolli, S. Ceravolo, M. Incurvati, F. Iungo, M. Paris, M. Preger, P. Raimondi, C. Sanelli, F. Sardone, F. Sgamma, M. Troiani

	Term.B	First pole	Second pole	Third pole	Fourth pole	Fifth pole	Term.A	Full wiggler
$(1/B\rho)\int(\partial B/\partial x)dz$	0.007	-0.009	0.010	-0.010	0.011	-0.014	0.003	-0.002
$(1/B\rho)\int(\partial^2 B/\partial x^2)x\,dz$	0.028	-0.009	-0.014	-0.012	-0.012	-0.014	-0.006	-0.039
$(1/120B\rho)\int(\partial^6 B/\partial x^6)x^5 dz$	5.8E-5	4.8E-4	1.3E-4	3.9E-4	1.7E-4	3.1E-4	1.9E4	0.002
K_1^{MAD} (m^{-1})	0.034	-0.017	-0.004	-0.022	-0.001	-0.027	-0.003	-0.040
$(1/B\rho)\int(\partial^2 B/\partial x^2)\,dz$	-3.4	0.26	0.18	-0.034	0.049	-0.082	0.43	-2.6
$(1/24B\rho)\int(\partial^6 B/\partial x^6)x^4\,dz$	-0.027	0.19	-0.067	0.16	-0.086	0.14	-0.079	0.23
K_2^{MAD} (m^{-2})	-3.43	0.46	0.12	0.13	0.0	0.05	0.35	-2.3
K_3^{MAD} (m^{-3})	10	64	28	56	34	49	27	268
K_4^{MAD} (m^{-4})	-3.1E3	1.6E4	-9.2E3	1.5E4	-1.1E4	1.4E4	-7.1E3	1.5E4
K_5^{MAD} (m^{-5})	6.5E5	2.8E6	2.1E6	2.7E6	2.2E6	2.6E6	1.3E6	1.4E7
K_6^{MAD} (m^{-6})	-7.82E7	2.56E8	-2.59E8	2.56E8	-2.58E8	2.59E8	-1.32E8	4.4E7

Elastic and Inelasting Beam-gas scattering at SuperB

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

- With this MC approach a more precise evaluation of beam-gas lifetime can be done, and also estimate longitudinal position of losses (i.e. optimize position of possible collimators)

Beam-gas scattering

- **Elastic scattering-**
  loss at physical or dynamic aperture

  stored beam particle is deflected when scattered by a nucleus of the residual gas atom (classical Rutherford cross section)

- **Inelastic scattering-**
  loss at RF acceptance limit or off-momentum (phys. or dynamic like Touschek)
  - Bremsstrahlung: photon emission by a stored electron deflected by the nucleus
  - Energy transfer from the stored electron to the atom of the residual gas

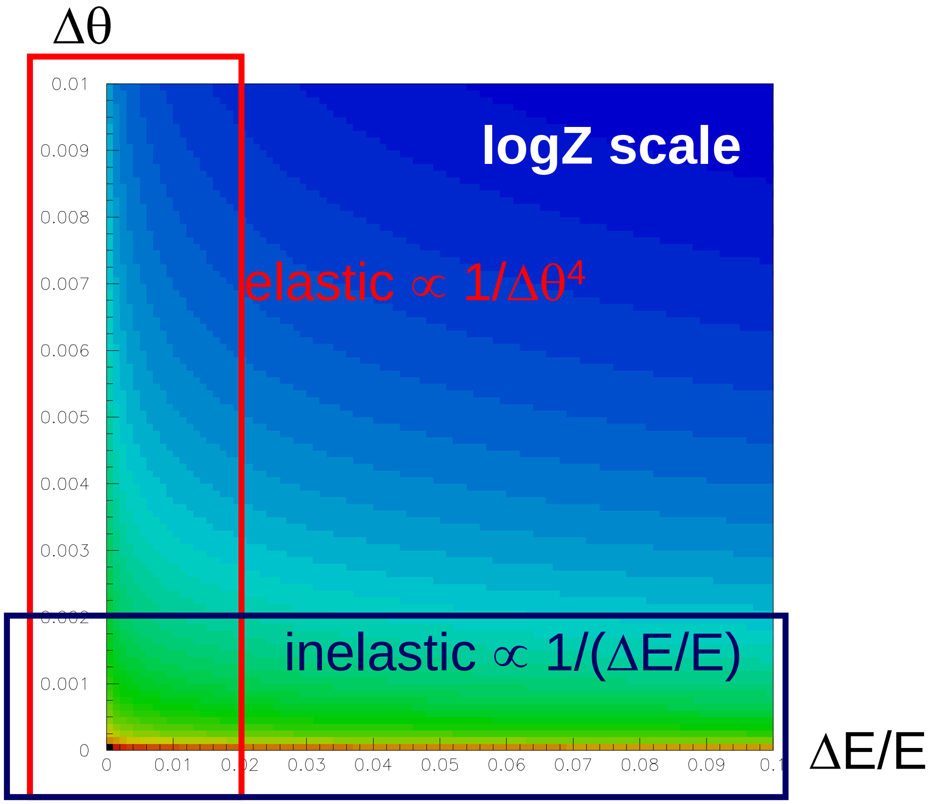
  Secondaries can be background source themselves- important near the IR (should be simulated directly with GEANT)

Beam-gas scattering

The two components actually belong to the same physics process. They need to be treated separately for practical purposes

they can be treated easily “a la” Touschek

Probability of beam-gas scattering



Program Flow Beam-gas 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 **beam-gas Bremsstrahlung scattering probability (or elastic beam-gas scattering)** all along the ring every 5 magnetic elements. Pressure and gas composition can vary along the ring- now constant

Tracking of scattered particles:

Start with transverse gaussian distribution and proper **energy spectra (or divergence distribution)** every 5 elements: track over many turns. Physical aperture now simply assumed circular with R=2cm except for IR: 1cm at QD0

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

Beam-gas inelastic scattering

usually the gas Bremsstrahlung lifetime is estimated from the integrated cross section

$$\boxed{\frac{1}{\tau_{\mathrm{Brems}}} = \rho\,\sigma^{N}_{\mathrm{inel}}\,c}$$

with

$$\sigma^{N}_{\mathrm{inel}} = 4r_e^2\,Z^2\alpha\,\frac{4}{3}\left(\ln\frac{183}{Z^{1/3}}\right)\left(\ln\frac{1}{\varepsilon_{\mathrm{RF}}}-\frac{5}{8}\right)$$

$\rho\ [\mathrm{m}^{-3}] = 3.217\times10^{22} P\ [\mathrm{Torr}]$ atoms/cm^3

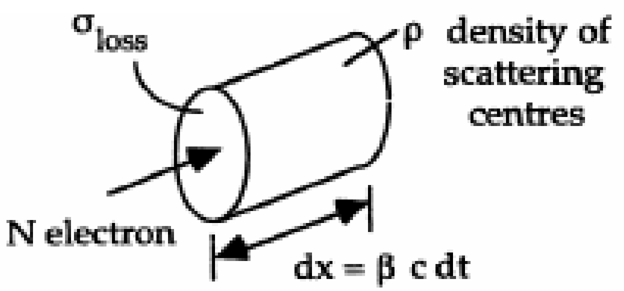
c speed light

The number of particles lost dN per unit time is proportional to the cross-section, the number of scattering centres and the number of incident particles.

$$dN = -N\rho\sigma_{loss}dx$$

$$\frac{1}{N}\frac{dN}{dt} = -\rho\sigma_{loss}\beta c$$

$$\left(N = N_0\,e^{-t/\tau}\right)$$



I compared the simulation results to the gas Bremss. lifetime estimated from this integrated cross section

Beam-gas Bremsstrahlung scattering-MC technique

$$\frac{1}{\tau} = \rho\left(\frac{d\sigma}{du}\right)c$$ frequency of a beam-gas scattering

u=Δp/p

$\frac{d\sigma}{du}$ differential cross section

$$\frac{1}{\tau} = \rho c \sum_{L} \left(\underbrace{\int_{u_{min}}^{u_{max}} \frac{d\sigma}{du} du}\, \frac{\Delta L}{L} \right)$$

frequency of a beam-gas scattering for a tracked particle

MC technique: uniform extraction of N_{MC} between u_{min} and u_{max} weighted with the cross section

$$\sum_{1}^{N_{MC}} \frac{d\sigma}{du}(u_{max} - u_{min}) / N_{MC}$$

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

rate of losses due to beam-gas scattering for N (particles/bunch)

τ_{ine} is the calculated beam-gas Bremsstrahlung lifetime

Beam-gas Inelastic scattering

- differential cross section for energy loss from photon emission at the nucleus (Bremsstrahlung):

we consider both nuclear and electrons interactions

$$\frac{d\sigma}{du} = 4\alpha\, r_e^2\, Z\,(Z+1)\,\frac{4}{3u}(1-u+.75u^2)\ell n\left(\frac{183}{Z^{1/3}}\right) \quad (4.1)$$

$$u = \frac{k}{E}\,. \quad (4.1a)$$

[A. Chao and Tigner Handbook]

[H. DeStaebler]

like Touschek with ΔE/E<0 for primary electrons

particles undergoing inelastic scattering are lost either for physical/dynamic aperture or for exceeding RF bucket

Beam-gas Inelastic scattering Simulation Results June 08 lattice

from formula: P = 1 nTorr, Z = 8

$\tau_{\mathrm{Brems}} = 4 \cdot 10^5$ s

from MonteCarlo: P = 1 nTorr, Z = 8

$\tau_{\mathrm{Brems}} = 3.2 \cdot 10^5$ s

from MC: P = 3 nTorr , Z = 8

$\tau_{\mathrm{Brems}} = 10^5$ s ~ 28 hr

for 1 bunch at 1.5 mA

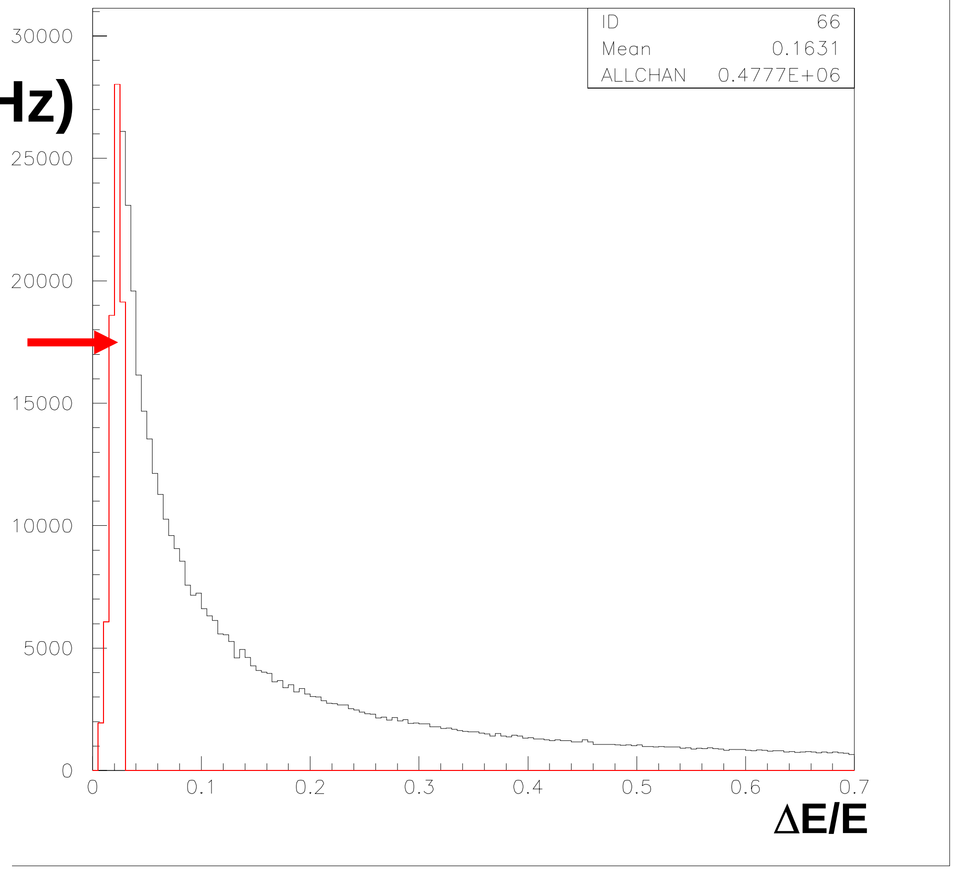
Tot. Losses = 480 kHz

(IR Losses = 10 kHz)

Beam-gas Bremsstrahlung:

$$N\frac{d\sigma}{du}(u_{max}-u_{min})/N_{MC}\cdot dL/L\,\rho\, c$$

loss rate(Hz)



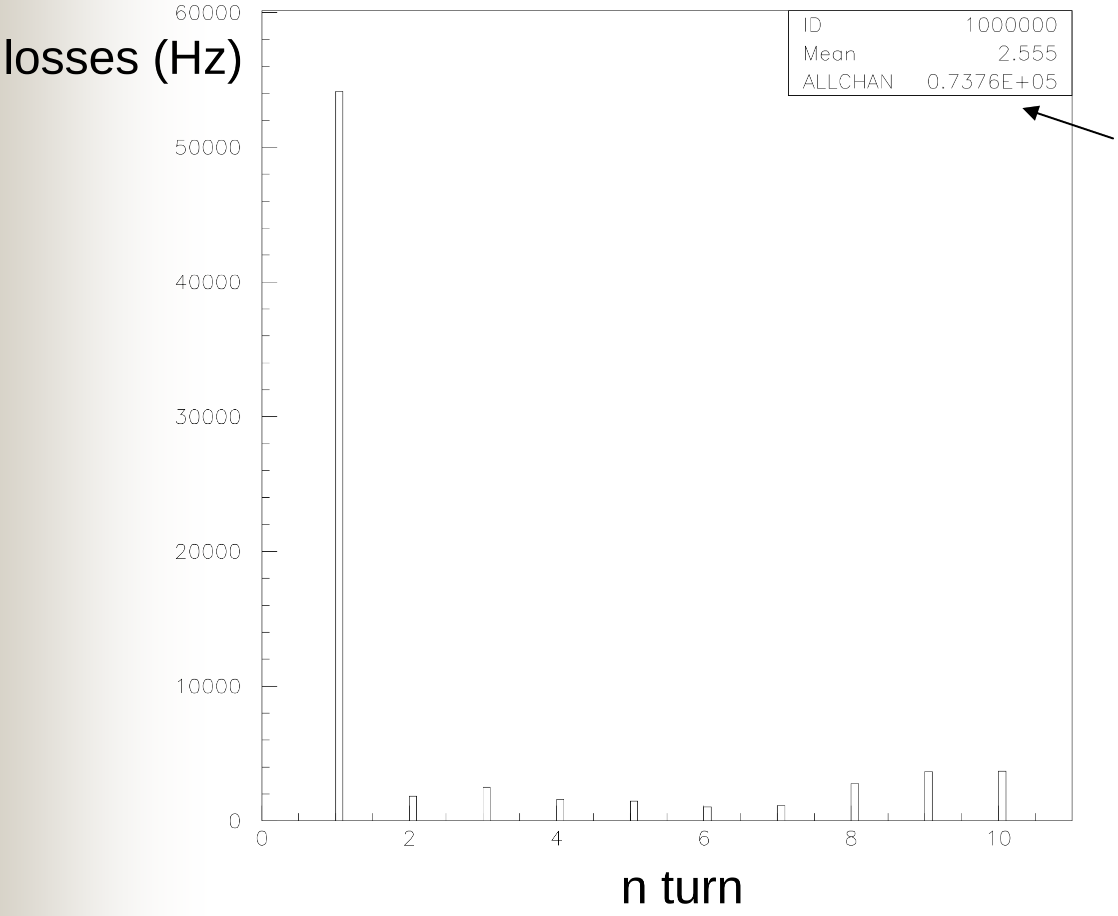
losses for exceeding physical aperture

~ 20% of total losses

these are losses not taken into account with integrated cross section (enters only the RF acceptance)

Beam-gas Inelastic scattering

losses for exceeding physical aperture versus machine turn number

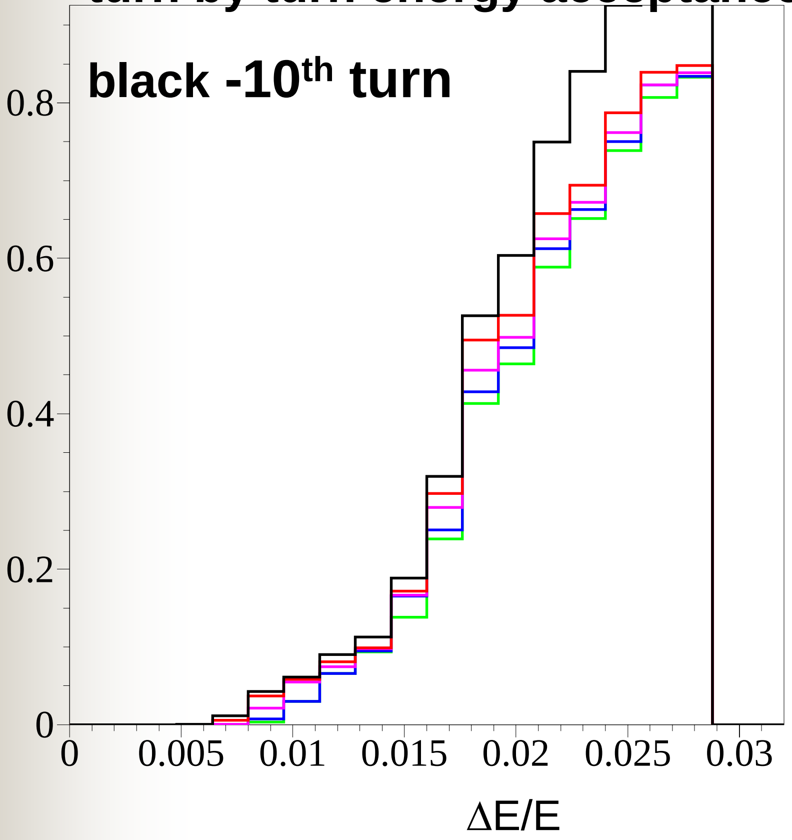


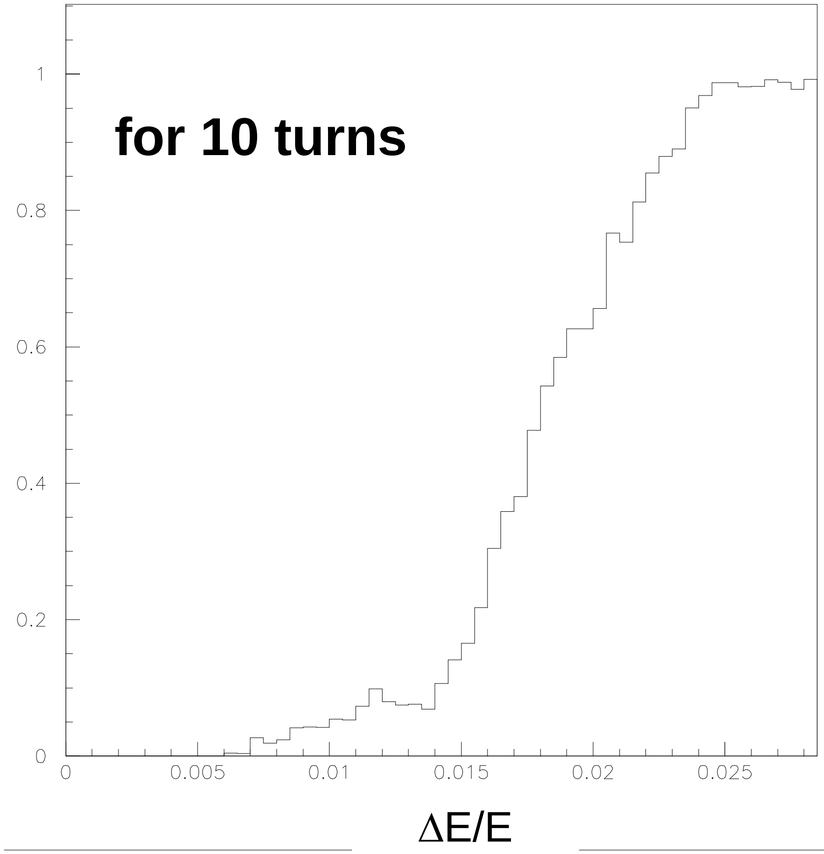
Losses exceeding phys. aperture
= $0.7 \cdot 10^5$ Hz
~ 20% of total losses

Tot. Losses = $4.8 \cdot 10^5$ Hz
(taken into account for lifetime estimation)

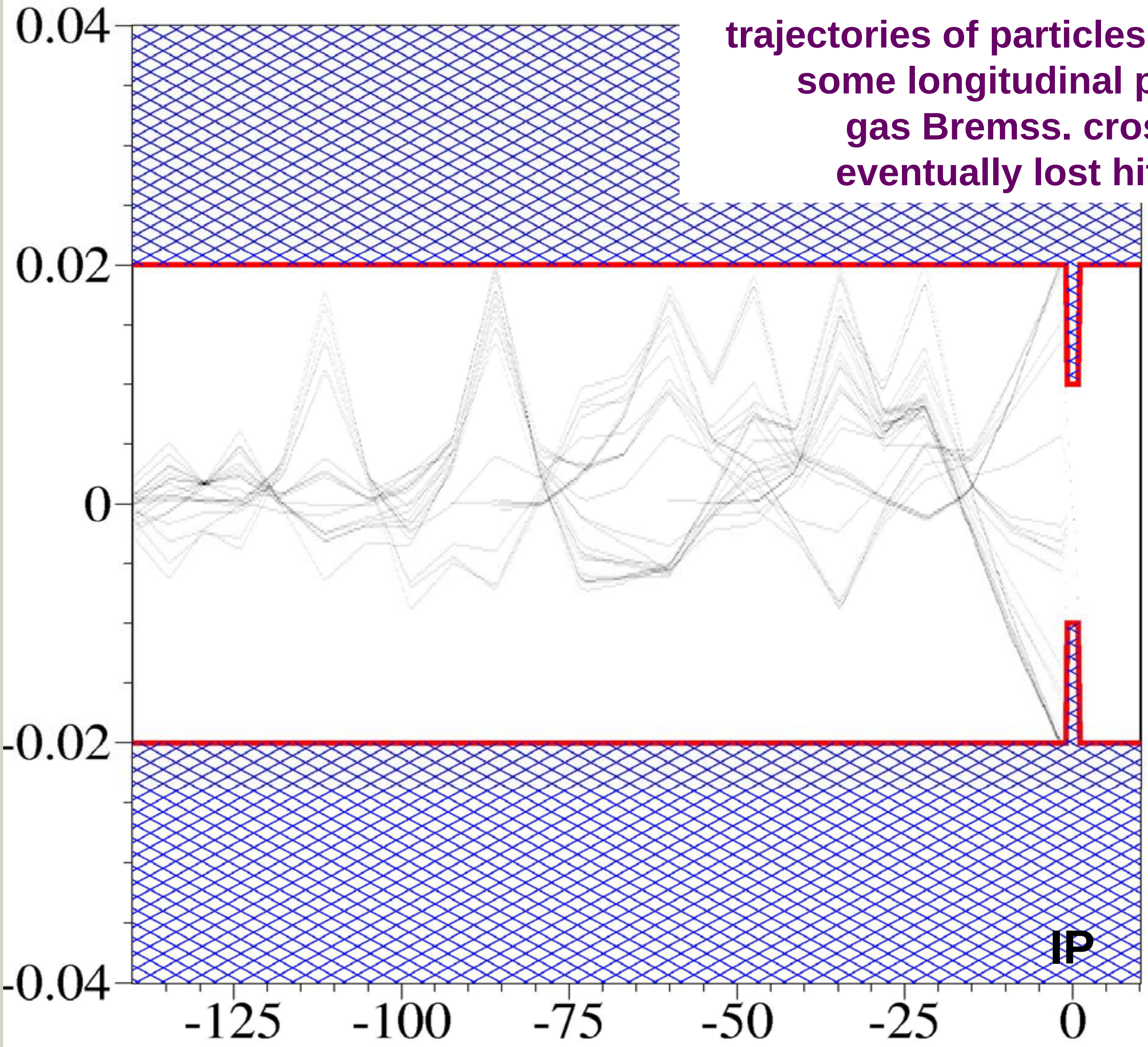
Beam-gas Inelastic scattering

Energy acceptance with the June 08 LER lattice


turn by turn energy acceptance



Beam-gas Inelastic scattering



trajectories of particles that are scattered in some longitudinal point according to the gas Bremss. cross section, and are eventually lost hitting the beam pipe

Elastic beam-gas scattering

Giving a circulating electron a kick θ results is an oscillation

$$u(s) = \theta_i \sqrt{\beta(s)\beta_i}\ \sin(\varphi(s) - \varphi_i)$$

need to track for many turns

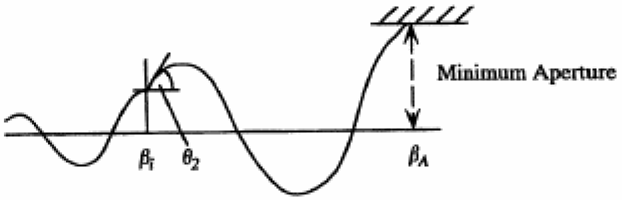
The maximum amplitude is

$$Max\,|u(s)| = A = \theta_i \sqrt{\beta_A \beta_i}$$

If A exceeds the physical or dynamic aperture the particle is lost

$$\theta_i \geq \sqrt{\frac{1}{\beta_i}\left(\frac{A^2}{\beta_A}\right)_{\min}} = \sqrt{\frac{H}{\beta_i}}$$

Where H is the machine acceptance



Loss of electrons - Calculate collision cross-section that leads to a deflection angle greater than a maximum θ_{max} defined by the acceptance of the ring. Integrating dσ from θ_{max} to π:

$$\sigma_{loss} = 2\pi \int_{\theta_{max}}^{\pi} \frac{d\sigma}{d\Omega} \cdot d\Omega = \frac{\pi}{2}\left(\frac{Z r_0}{\gamma}\right)^2 \cot^2\left(\frac{\theta_{max}}{2}\right)$$

$\theta_{max} = \sqrt{H/\beta_i}$ is a small angle & approximating tan θ_{max} ~ θ_{max}

$$\sigma_{loss} = \frac{2\pi Z^2 r_o^2}{\gamma^2} \cdot \frac{1}{\theta_{max}^2} = \frac{2\pi Z^2 r_o^2}{\gamma^2} \frac{\beta_i}{H}$$

Averaging over the ring

$$\boxed{\sigma_{loss} = \frac{2\pi Z^2 r_0^2}{\gamma^2} \cdot \frac{\langle\beta\rangle}{H}}$$

nuclear Coulomb scattering integrated σ

Beam-gas elastic scattering- MC technique

$$\frac{1}{\tau} = \rho \left(\frac{d\sigma}{d\Omega} \right) c$$

frequency of a beam-gas scattering

$\frac{d\sigma}{du}$ Nuclear Coulomb differential cross section

$$\frac{1}{\tau} = \frac{1}{L} \rho c \sum_{L} \left(\int_{\vartheta_{min}}^{\vartheta_{max}} \frac{d\sigma}{d\Omega} \right) dL$$

frequency of a beam-gas scattering for a tracked particle

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

rate of losses due to beam-gas scattering for N (particles/bunch)

τ_{ela} is the calculated beam-gas elastic lifetime

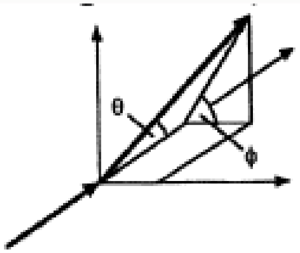
Elastic beam-gas scattering

differential cross section

$$\frac{d\sigma}{d\Omega} = 4r_e^2\ Z^2 \frac{\left(\frac{m}{p}\right)^2}{(\theta^2 + \theta_1^2)^2} \, ,$$

[A. Chao and Tigner Handbook]

[H. DeStaebler]



$$d\Omega = \sin\theta\, d\theta\, d\phi$$

$$\theta_1 = \alpha Z^{1/3} \left(\frac{m}{p}\right) \, .$$

The screening of the atomic electrons is accounted for by the angle θ_1. Any nuclear form factor effects are neglected, which requires $q \approx E\theta < q_{\max} = 137\ \mathrm{m}/A^{1/3}$. The energy lost by the beam particle is $q^2/2A$ which can safely be neglected.

from MC: **P = 1 nTorr , Z = 8**

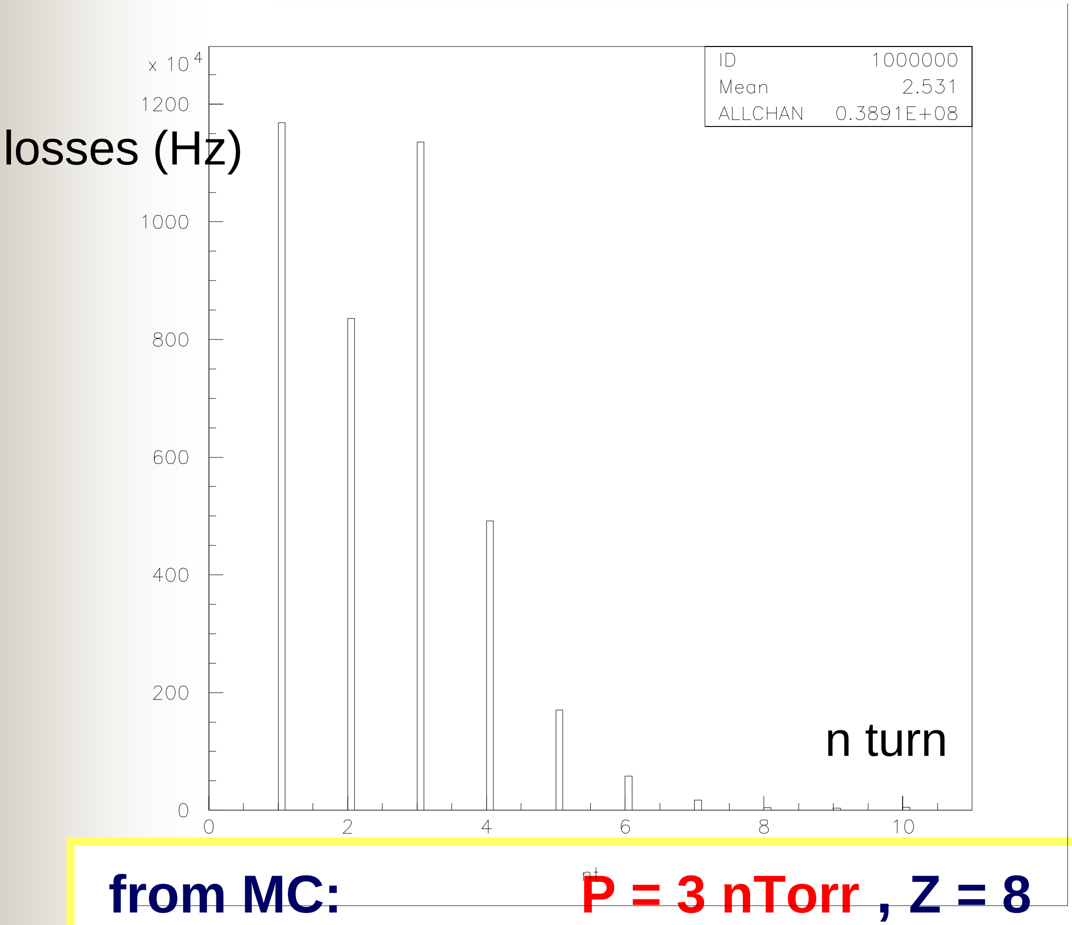
τ_{elast} = 3960 s ~ 66 min

for 1 bunch at 1.5 mA

Tot. Losses = 13 MHz

IR Losses = 12 MHz ⇐

Elastic beam-gas scattering



June 08 lattice

from MC: **P = 3 nTorr , Z = 8**

τ_{elast} **= 1320 s ~ 22 min**

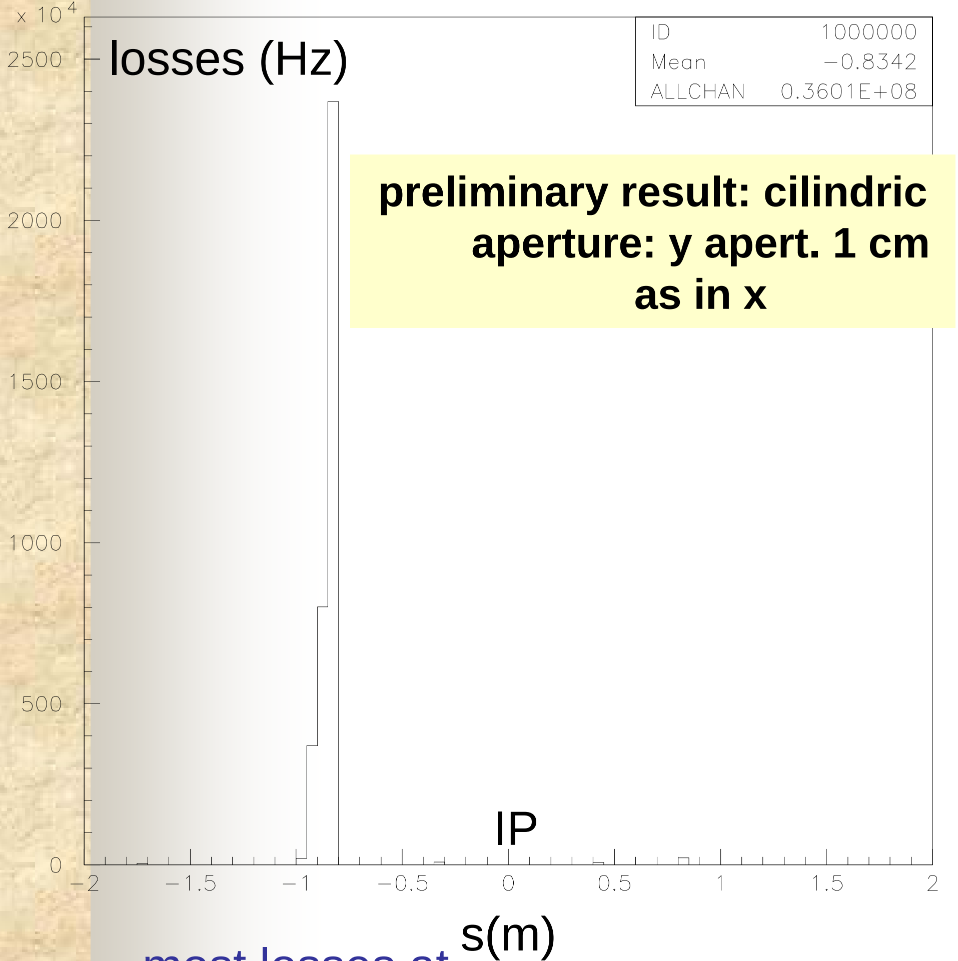
Tot. Losses = 39 MHz

IR Losses = 36 MHz

for 1 bunch at 1.5 mA

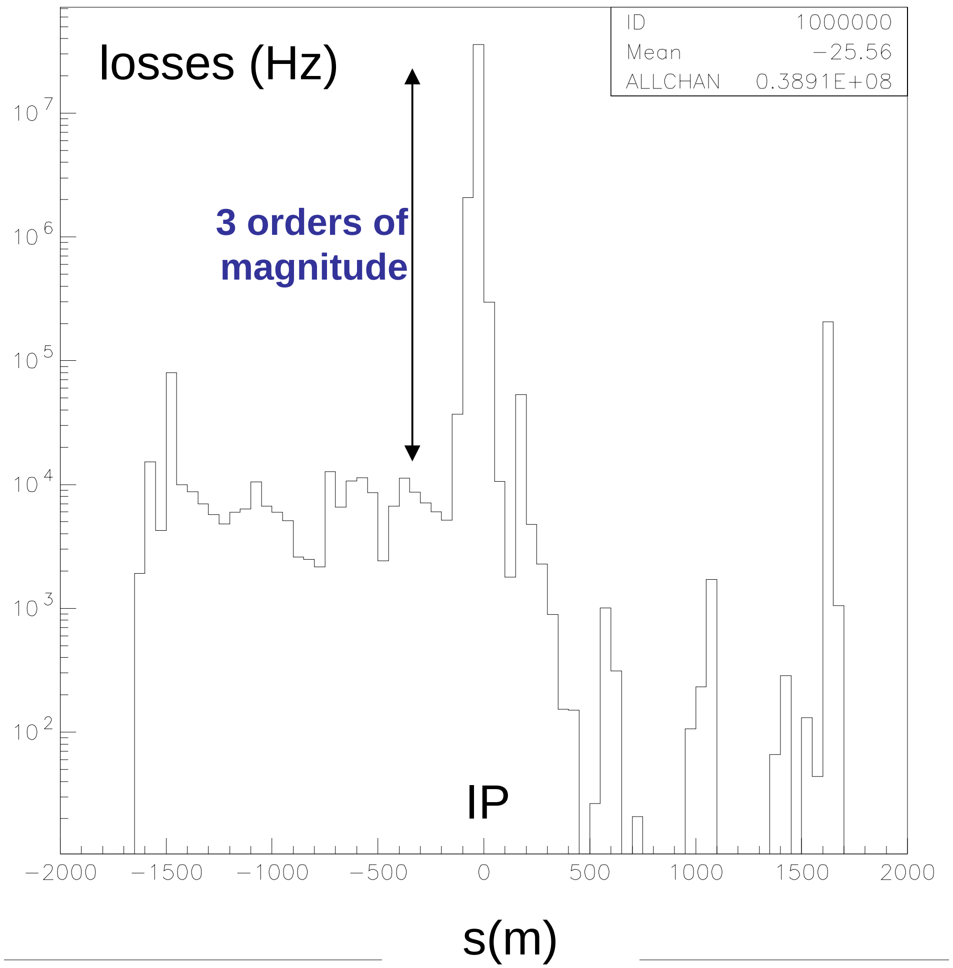
Elastic beam-gas scattering

zoom at IR



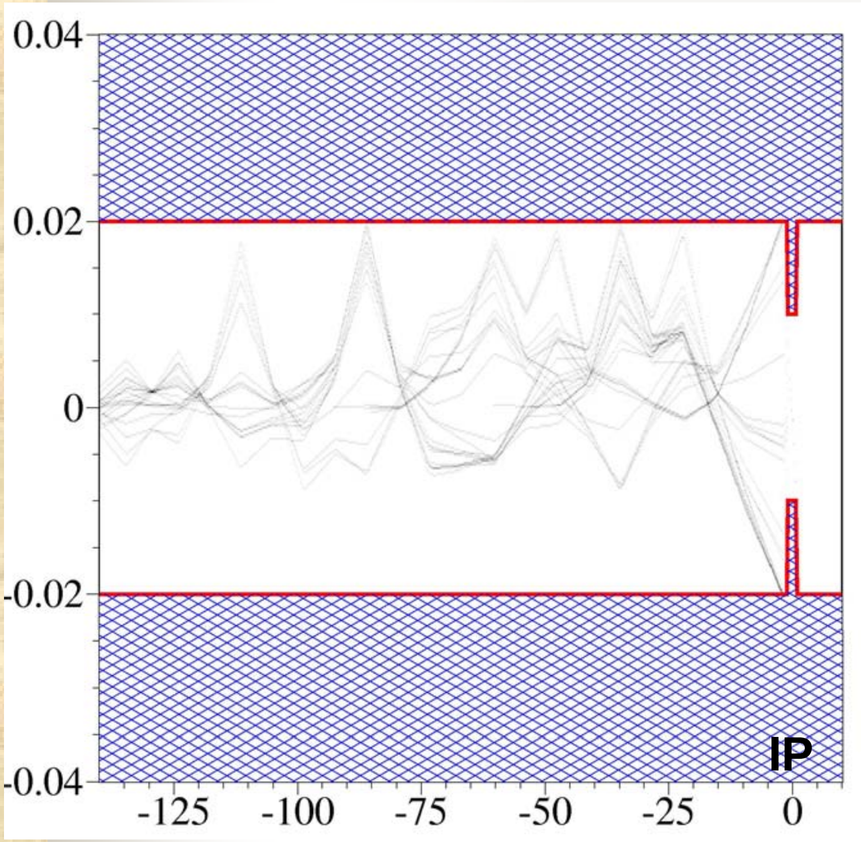
preliminary result: cilindric aperture: y apert. 1 cm as in x

most losses at QF0 exit

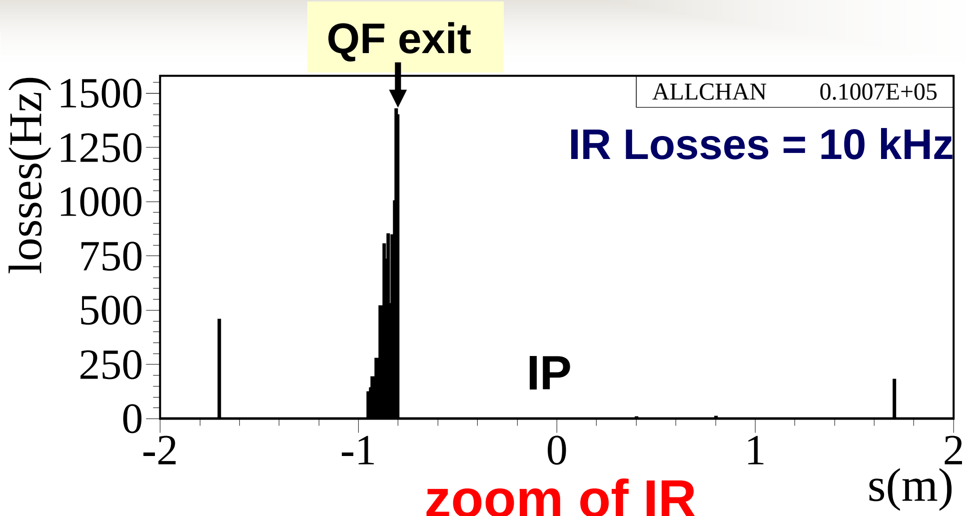


3 orders of magnitude

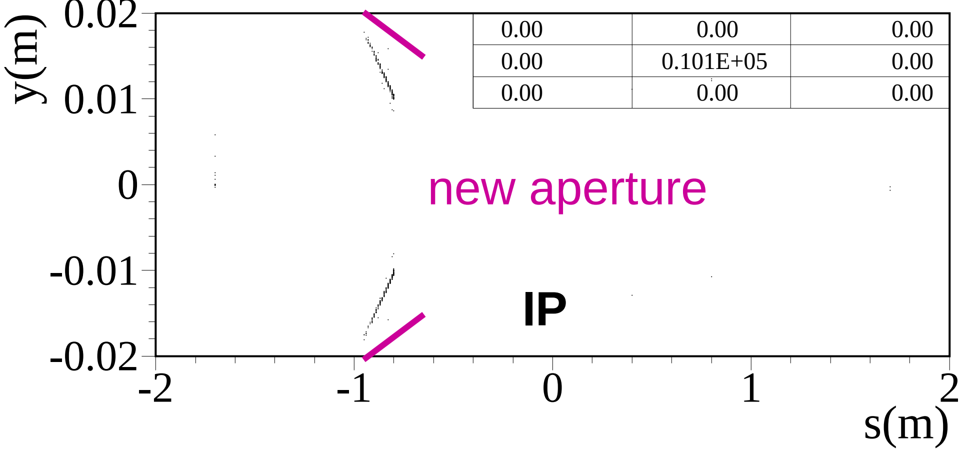
Beam-gas Inelastic scattering



trajectories of particles that are scattered in some longit. point according to the gas Bremss. cross section, and are eventually lost hitting the beam pipe



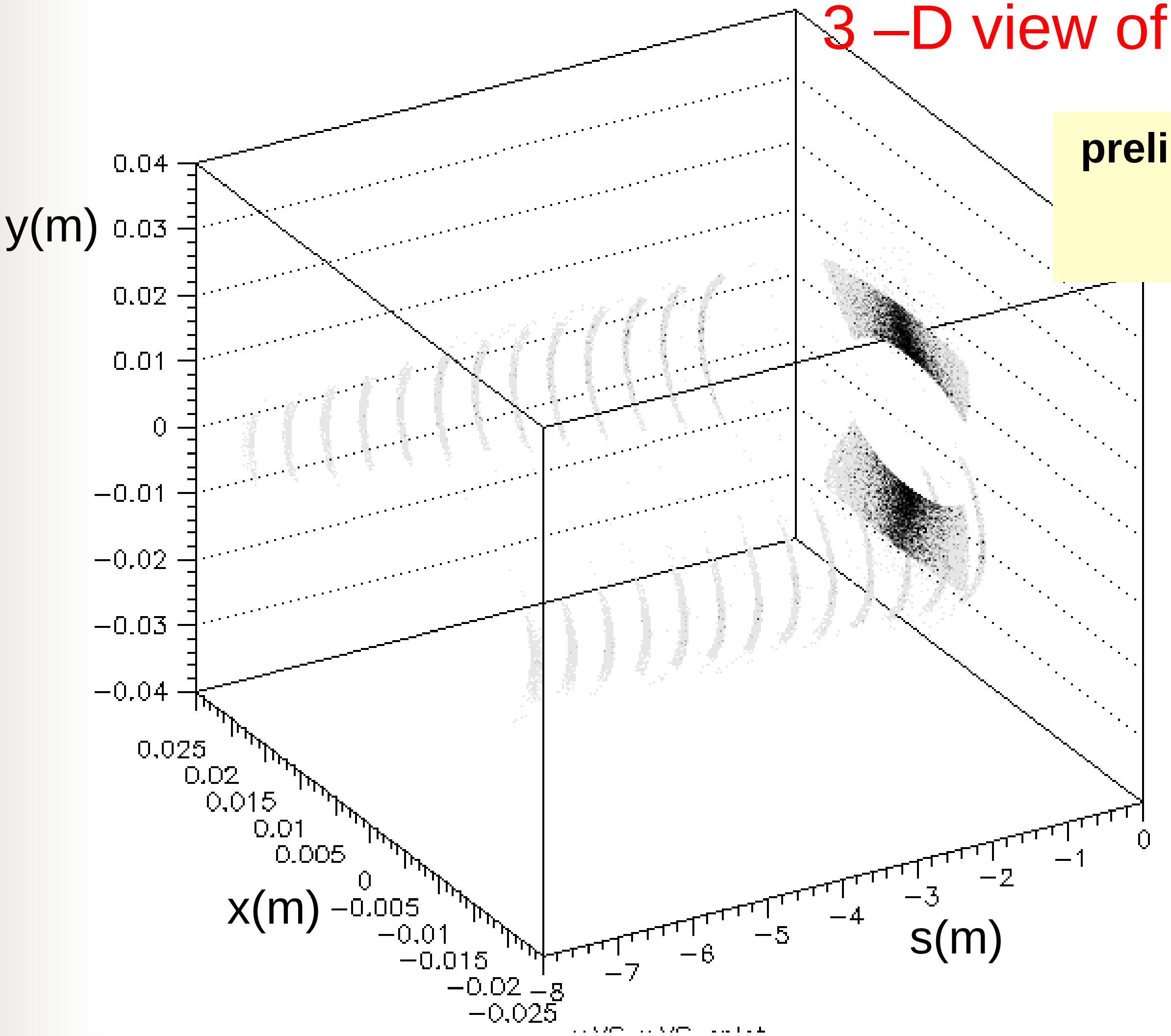
zoom of IR



losses are concentrated in the vertical plane at the exit of QF of the IR doublet

Elastic beam-gas scattering

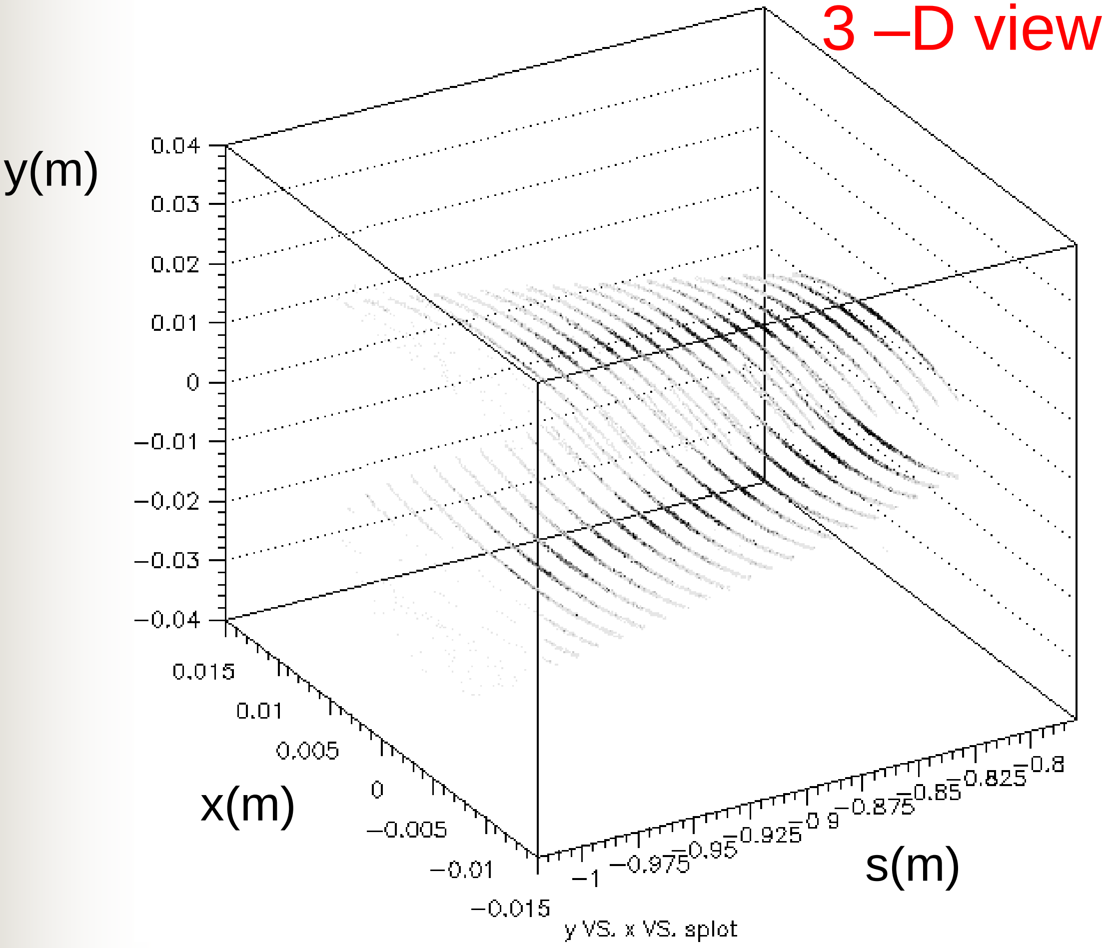
3 –D view of IR losses in y



preliminary result: cilindric aperture: y apert. 1 cm as in x

Beam-gas elastic scattering

3 –D view of IR losses in y



Conclusions

TOUSCHEK:

- at SuperB: simulations with latest IR design is ongoing with careful collimators studies – soon new tracking of secondaries
- Tracking of secondaries in detectors is ongoing for the June08 lattice, in collaboration with background simulation group
- at DAFNE: background and lifetime evaluations with present crab waist lattice : comparison with data is ongoing both for bkg rates and lifetime

BEAM-GAS:

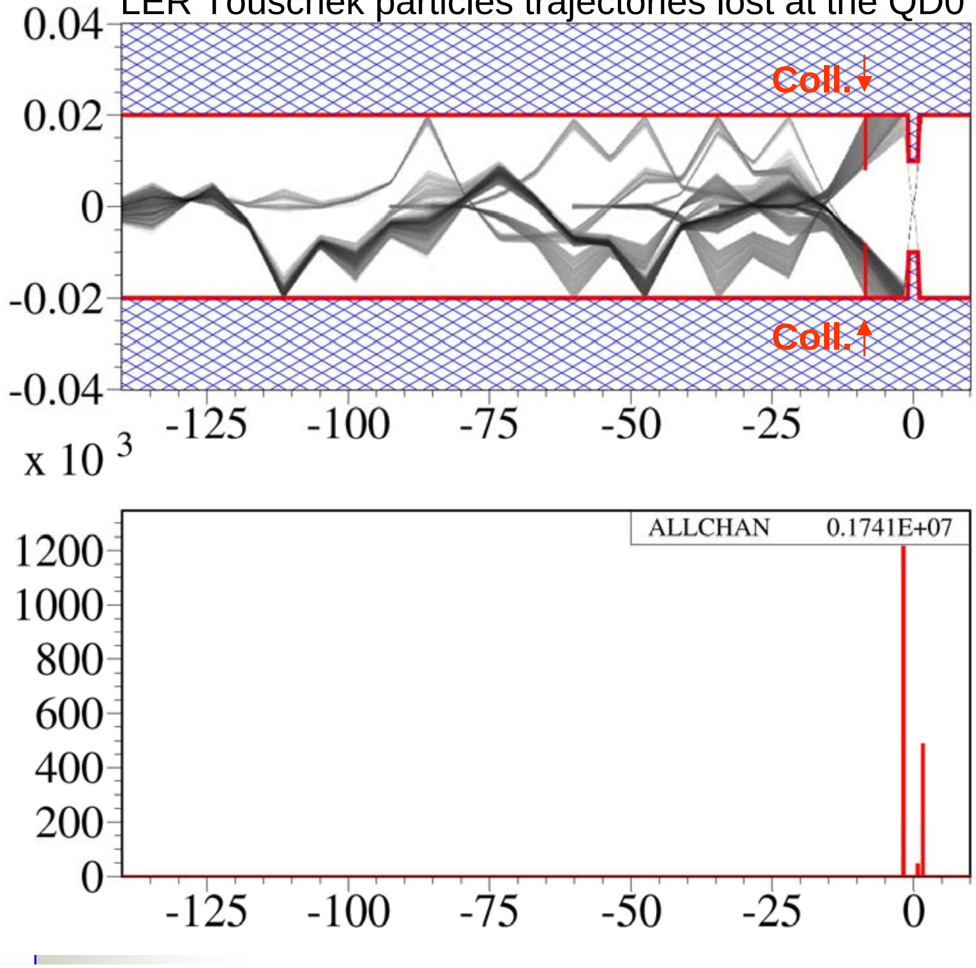
- simulation code in good progress
- evaluate the effect with Jan09 SuperB IR design and compare with DAFNE result (small effect)

Back-up slides

LER Touschek particles lost at IR
NO COLLIMATORS inserted

Touschek lifetime ≈ 24 min

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

parameters for simulations

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

rf accept. =2.9 %

machine turns = 5

K=0.25%

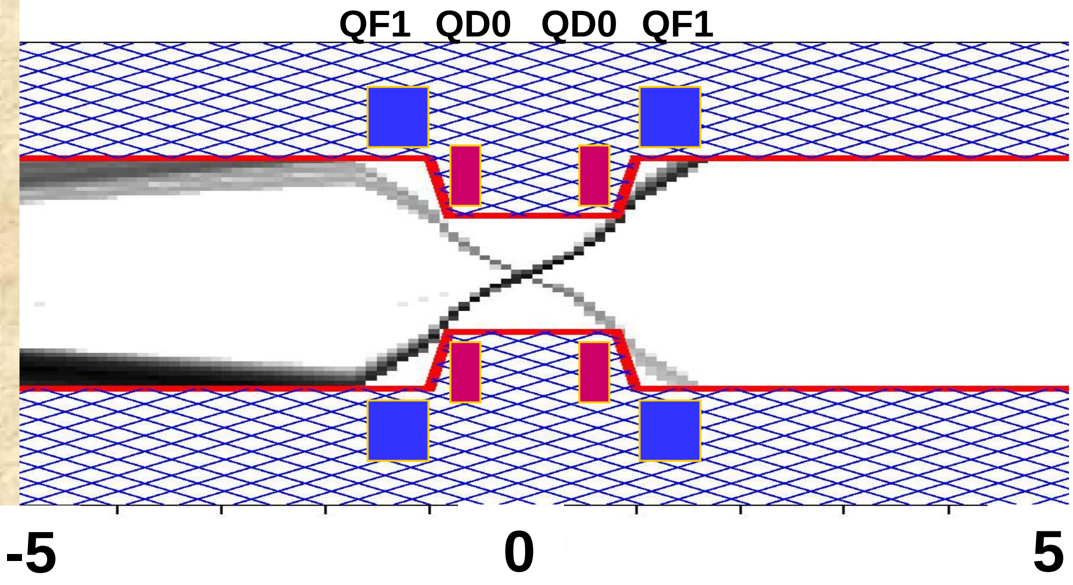
ε_x=2.8 nm ; σ_z=5 mm

June 08 lattice

HER Touschek particles lost at IR

<u>NO</u> COLLIMATORS inserted

Touschek lifetime ≈ 40 min

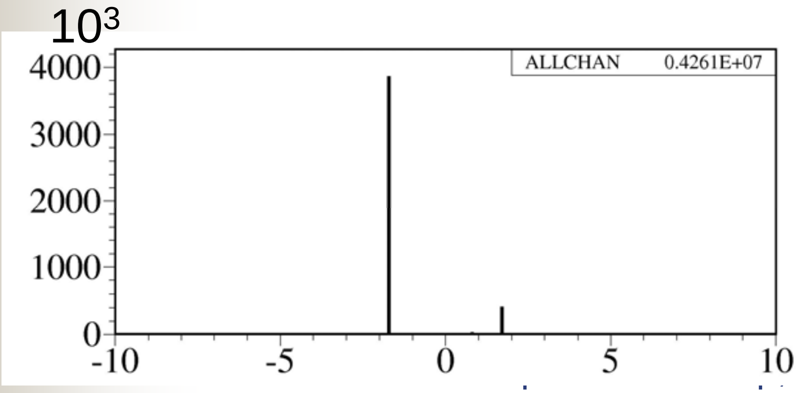


IR Losses (|S|<2m)= 4.2 MHz

for 1 bunch with I_{bunch} =1.49 mA

IR Losses (|S|<2m)= 5.2 GHz

for nominal full current



<u>parameters for simulations</u>

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

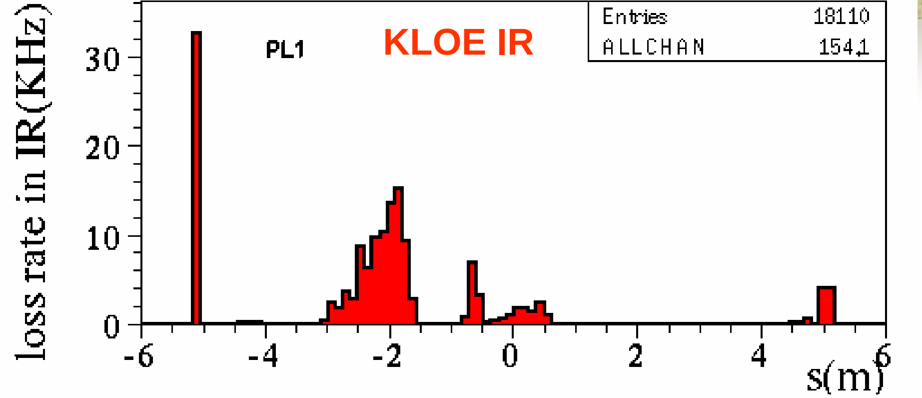
rf accept. =2.9 %

machine turns = 5

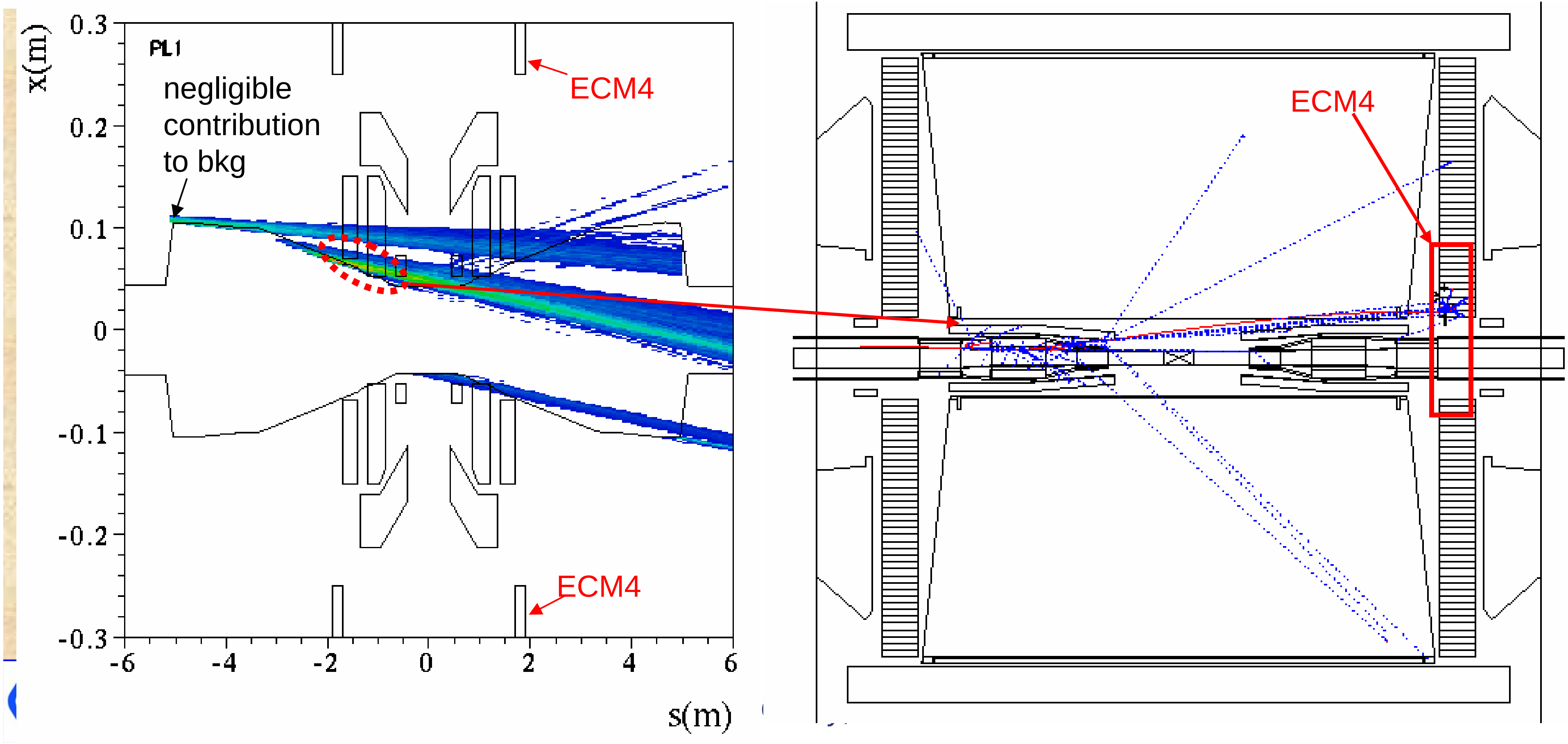
K=0.25%

ε_x=1.8 nm ; σ_z=5 mm

complicated prediction on detector



complex to generate and to track in detectors (detailed geometry and tracking of secondary)



Simulation of very rare processes

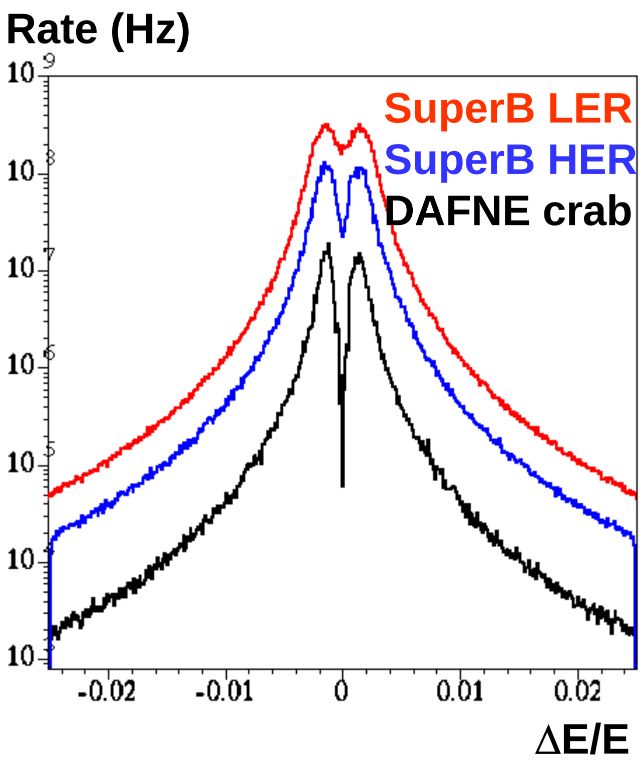
many particles in colliding bunches but only few of them are lost for these processes

example:

probability for Touschek effect

Coulomb scattering of charged particles travelling together causes an exchange of momentum between the tranverse and longitudinal directions.

Due to relativistic effects, the momentum transferred from the tranverse to the longitudinal direction is enhanced by γ.



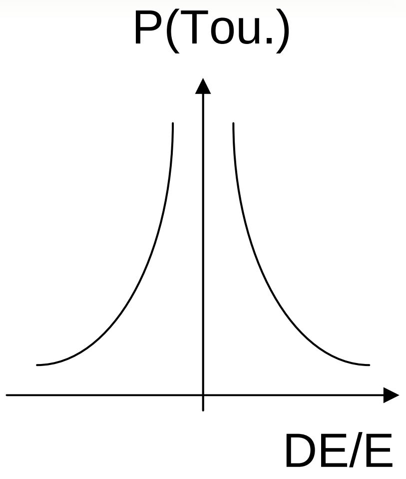
particles are lost if their ΔE/E

1) exceeds the rf bucket

2) exceeds the momentum aperture determined by the lattice.

loss probabilty increases with ΔE/E

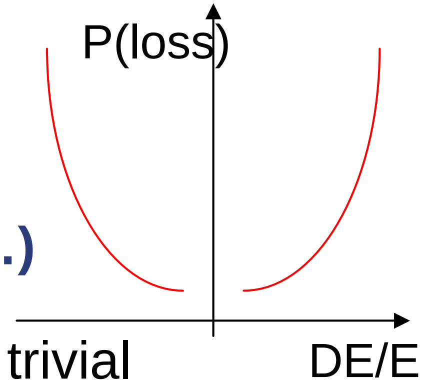
Touschek energy spectra related mostly to beam parameters (i.e. bunch volume, ε, σ_p, bunch current…)



With a given energy spectrum P(E)
(see next slide) one can:

1. extract according to P(E) or
2. Use a uniform extraction and use P(E) as a weight

Particle losses related mostly to machine parameters/optics (i.e. physical aperture, phase advance, dispersion, …)



We use 2. to cope with tails of both distributions (non trivial statistical errors with large weights)

$O(10^{-2})$ s per particle for 5 turns on 3 a Ghz Xeon cpu

Calculation of energy spectra

Starting formula:

Integrated Touschek probability

$$\frac{1}{\tau} = \frac{\sqrt{\pi} r_e^2 c N}{\gamma^3 (4\pi)^{3/2} V \sigma'_x \varepsilon^2} C(u_{\min})$$

$$\frac{1}{\tau} = \int_{\varepsilon}^{\infty} P_{Tou}(E)\,dE$$

$$\varepsilon = \frac{\Delta E}{E} \qquad u_{\min} = \left(\frac{\varepsilon}{\gamma \sigma'_x}\right)^2$$

$$\sigma'_x = \sqrt{\frac{\varepsilon_x}{\beta} + \sigma_p^2 \left(D'_x + D_x \frac{\alpha_x}{\beta_x}\right)^2}$$

V = bunch volume= $\sigma_x \cdot \sigma_y \cdot \sigma_l$

C(umin) accounts for Moller x-section (polarization is included) and momentum distribution

For a chosen machine section the Touschek probability is evaluated in small steps (9/element) to account for the beam parameters evolution for 100 ε values.

Use an interpolation between the calculated ε values according to the Touschek scaling law: $A_1 \cdot \varepsilon^{-A_2}$

Background reduction: multiple step process

- Simulation of main different background sources
- Propagation of background generated particles into the detector region → simulation of interactions and showers in and nearby the detectors with MC
- Shieldings optimization: Masks + collimators

If detector background budget not satisfactory, readjustments of

- critical beam parameters
- IR design