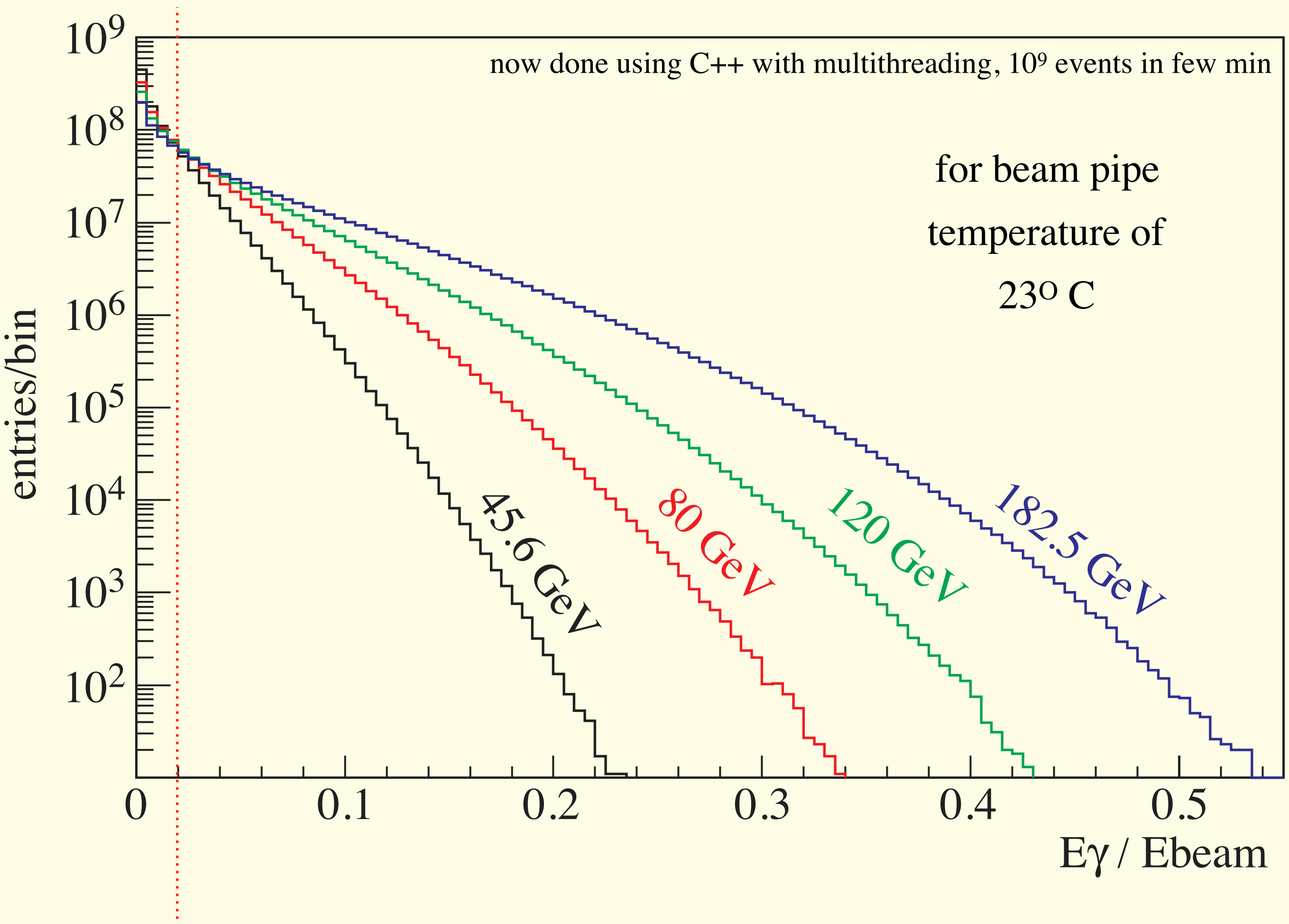
Beam losses in interaction region

covering in particular

- **thermal photon scattering, overall rates**
- **detailed tracking all around the ring**
- **losses in interaction region**
- **discussion, mitigation of losses by collimation**

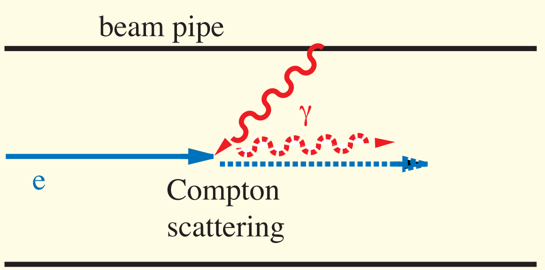
Thermal photon scattering

First described in [1987 by V. Telnov](), main single [beam lifetime limitation in LEP](),
[well measured]() and simulated using the algorithm described in [SL/Note 93-73]()



photon density

$\rho_\gamma = 5.3 \times 10^{14}$ m^{-3}



very roughly

0.07 eV thermal photons

boosted by γ^2 to GeV

energy loss from beam

Fraction lost, at 2% energy acceptance,

19% at 45.6 GeV 54% at 182.5 GeV, lifetime τ = 54 h

Rates, FCC-ee

Ebeam GeV	σ barn	Ne 10^{11}	#scat turn	Nb	ScatRate GHz
45.6	0.6498	1.7	569.0	16640	29.04
80 .0	0.6389	1.5	493.6	2000	3.03
120.0	0.6269	1.8	581.3	328	0.585
182.5	0.6095	2.3	722.1	48	0.106

At 182.5 GeV : 54% of the **722** scattered

or **387 e+, e- get lost** per turn and per bunch

Good goal :

get loss rates per bunch crossing in IP region << 1

Next slides : look at lattice, aperture

and use detailed Monte Carlo generation + tracking all around the ring

to see where particles get lost and in particular **how many get lost in the IP region**

Lattice and aperture

MAD-X lattice : fcc_ee_t_213_sol_b1 **now with solenoid,** for more details see

[Tilted Solenoid for MAD-X](#) [Comparison of tracking and maps for tilted solenoid with fringe fields](#) [Tracking through solenoid with overlapping fields in quadrupole using Geant4](#)

adding apertures, based on [CDR](#) (p.193ff)

35 mm radius, default, most of ring

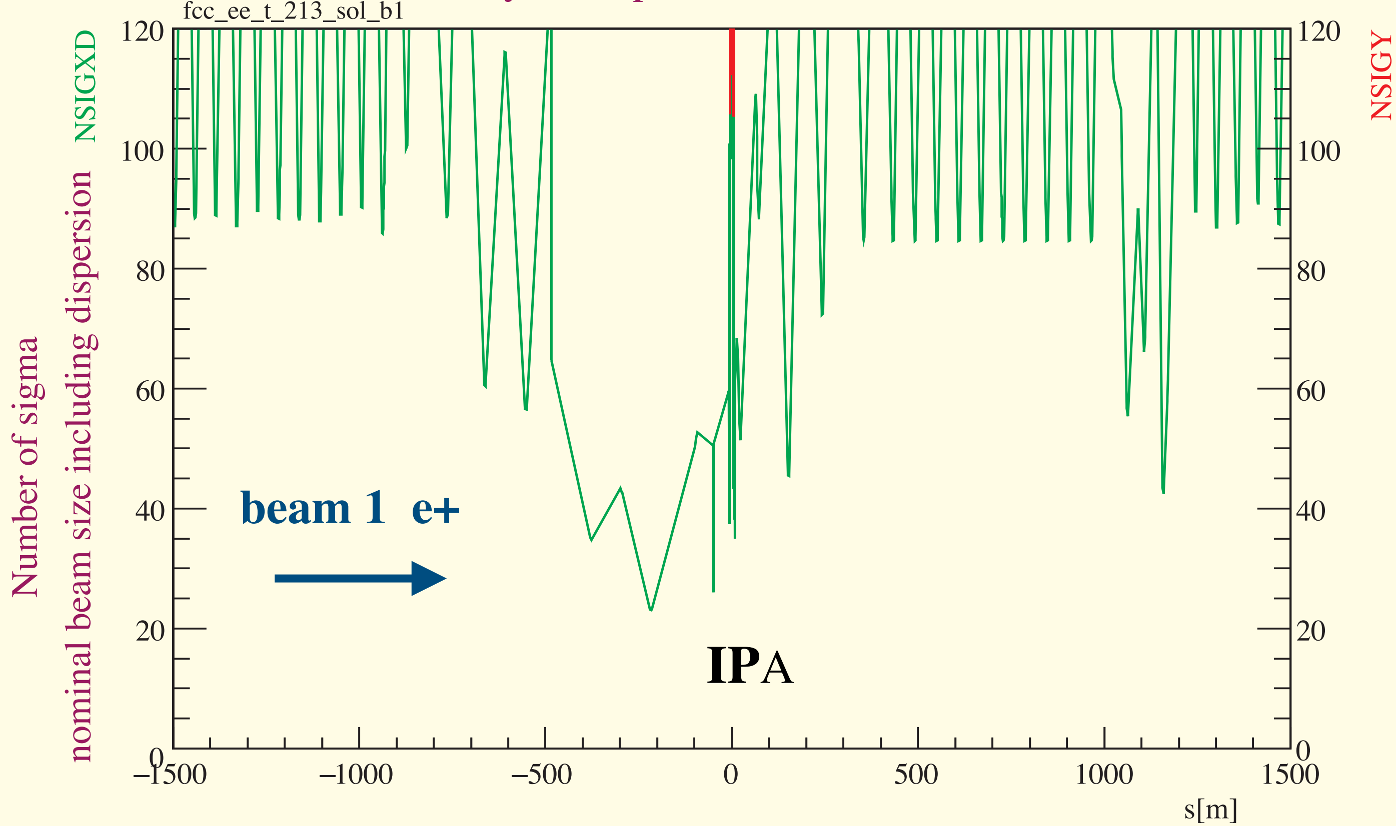
20 mm in QC2 region

18, 13 mm masks and

15 mm radius in IP region

Physical aperture 1.5km from IP, nominal beam

Beam aperture reduces significantly as seen by beam travelling to the IP, potentially resulting in concentration of losses in IP region

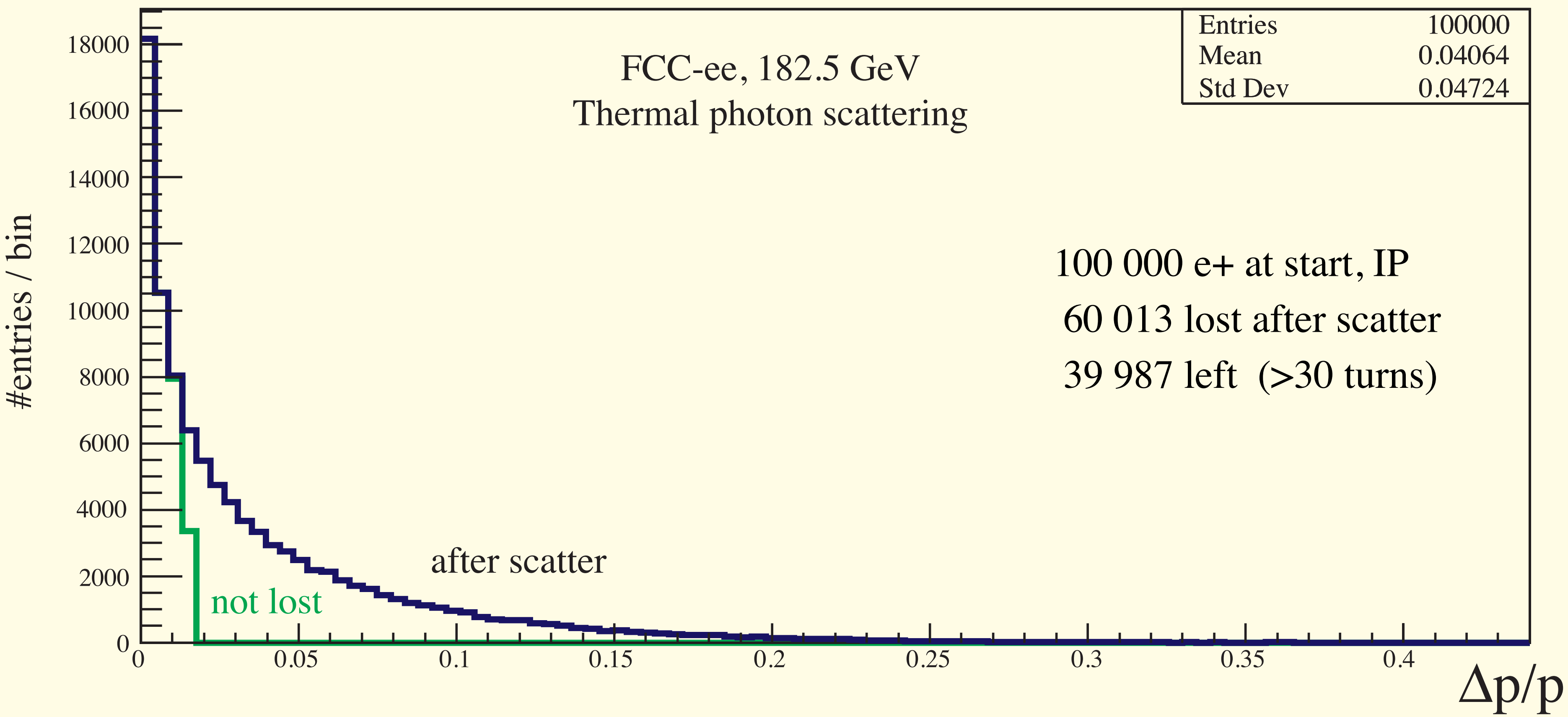


Monte Carlo generation + tracking full ring

Track n (here 10^5) **particles around the ring for n_{max} (~ 30) turns**

element by element, based on maps from MAD-X

Scatter every beam particle once in turn 1, uniformly distributed around ring



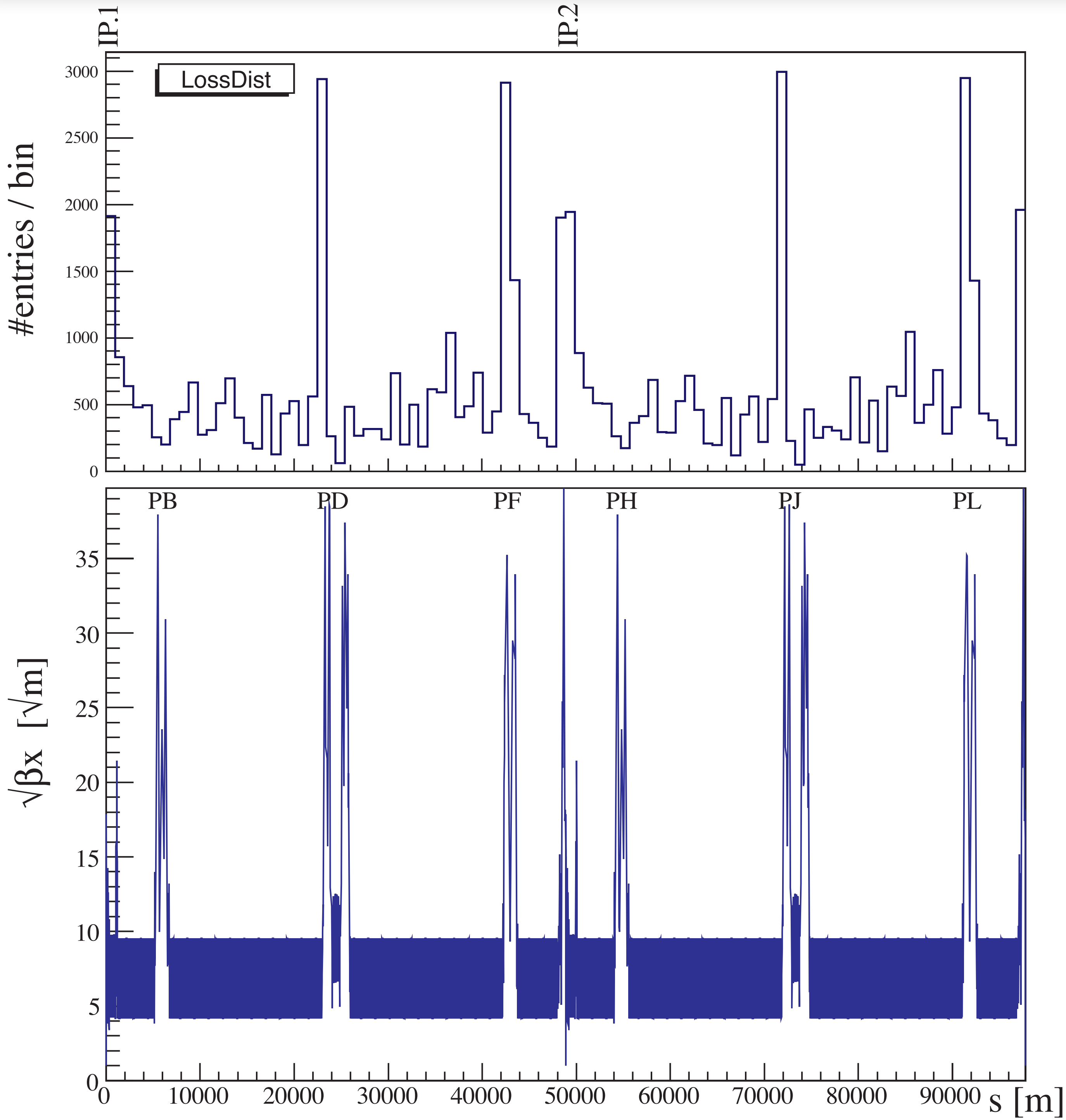
At present : using the ideal lattice translated from SAD. Solenoid, apertures, beam2 added by hand

granularity by element boundary : generation, aperture checks at end of elements

no errors, no misalignment, gaussian beams, RF and radiation here turned off

energy acceptance bit smaller and detuning with amplitude a bit larger than with SAD

Loss distribution around the ring



100 000 e+

tracked up to 30 turns

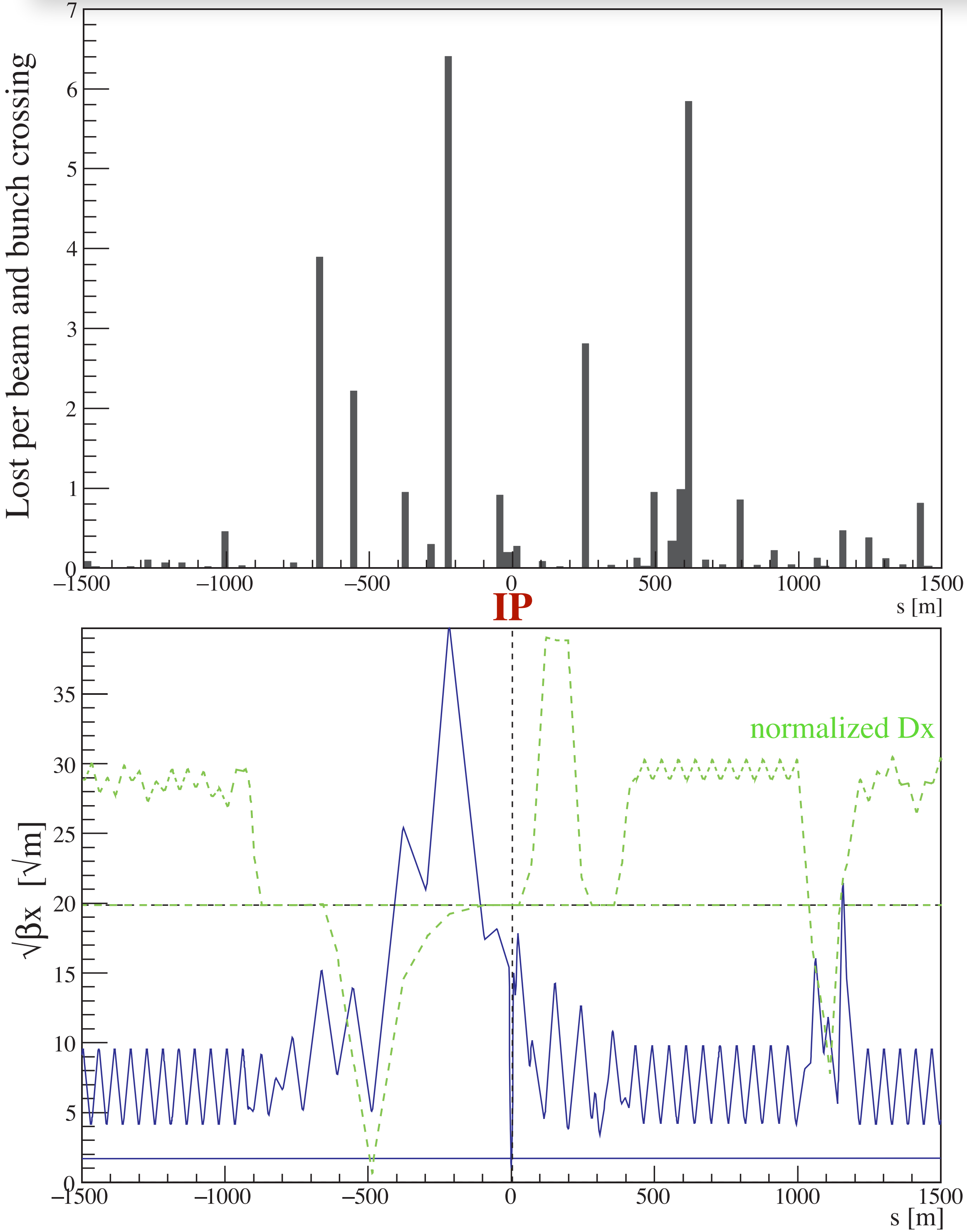
all scattered once

on 1st turn

uniformly distributed

around ring

Normalized loss distribution ± 1500 m around IP



Normalization (slide 3)
factor, here 722.1 / 100 000

Thermal γ 31.2 ± 0.5
lost per beam and crossing
within 1500 m from IP
at 182.5 GeV
of which
11.1 ± 0.3 within 300 m

Errors quoted are statistical
from tracking of 100 000
scattered particles

Impact, Mitigation

Thermal γ : halo generator both off momentum and large amplitudes by scattering with dispersion
similar effect from beam-gas scattering, see IPAC2018-MOPMF085 and O.Blanco MDI#22

LEP : beam gas dominant in early operation + after venting

major source of-off momentum and main lifetime limitation with collisions : beam-beam Bremsstrahlung
directed away from IP + lost on apertures and removed by collimation far from IP

Thermal γ scattering always there, also for perfect vacuum and without collisions
FCC-ee geometry and local IP-fields are such that off-momentum electrons rarely hit directly
the luminosity monitor but frequently generated secondary particles visible in the detectors

to be confirmed by detailed simulations under realistic conditions

Mitigation :

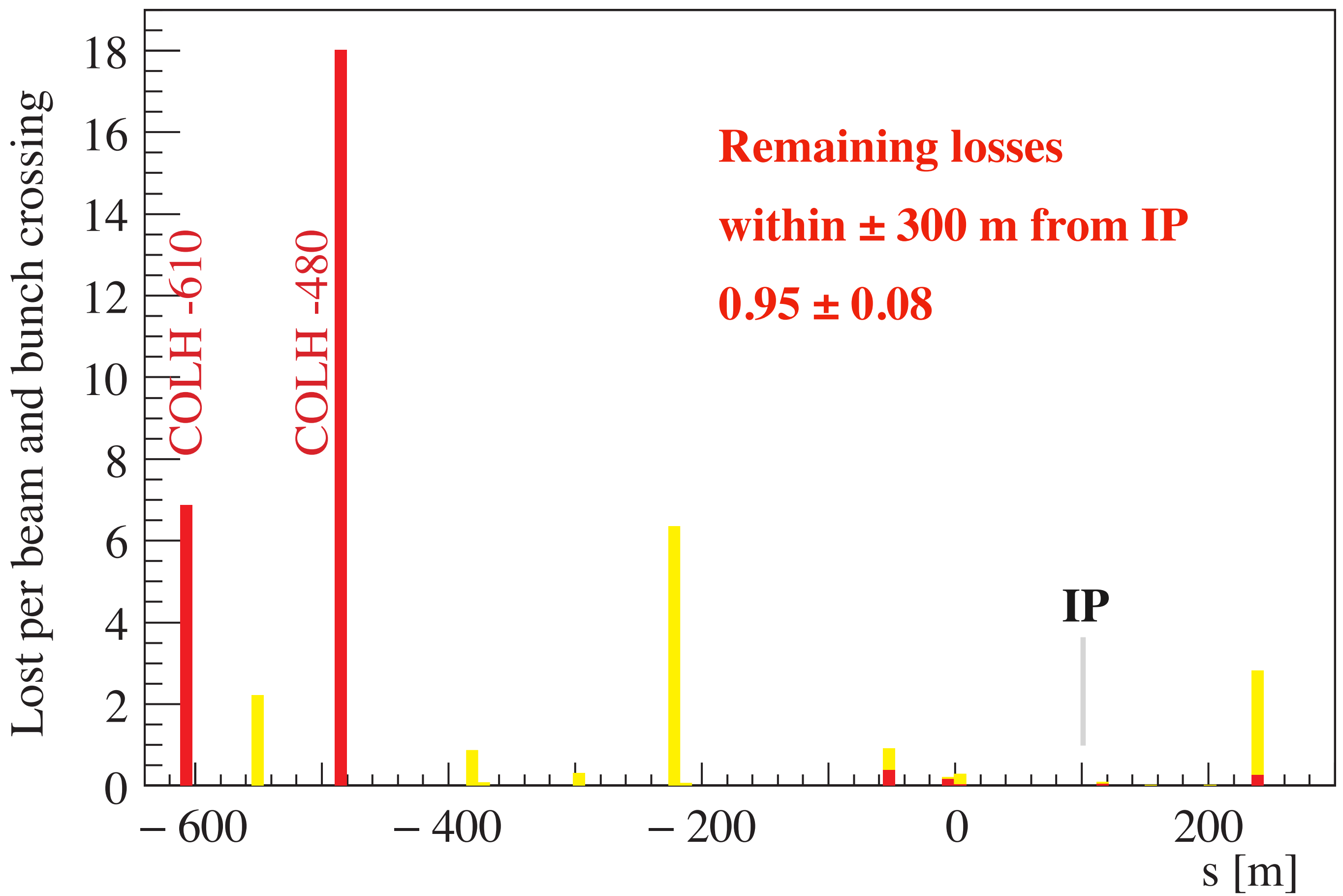
- Try to remove aperture bottlenecks close to IP — avoid high β and/or increase beam pipe at high β
- Use collimators to remove particle losses — further away from the IP
  attempt shown next slide

mitigation by off-momentum collimation

test with two horizontal off-momentum collimators

610 m and 483 m from IP at 14 σ including dispersion, cutting at ~ 2% ΔE /E

Losses now concentrated at these collimators



red : with, yellow without collimation

Discussion

Even for perfect vacuum and without collisions

there will always be losses by thermal photon scattering generating background particles at IPs

based on the (early) tracking results shown here, we expect from thermal photon scattering the loss of

~ 11 beam particles within 300 m from the IP without collimation and

~ 1 beam particle lost per beam, bunch passage and IP with collimation

Signature : off-momentum by few %, high amplitude, mostly in horizontal plane and losses impacting at low angle

Comparable to beam gas for a residual gas pressure of order 10^{-9} mbar (N_2, CO)

Probably not a major issue, but important to take into account and mitigate (as done for LEP)

Backup

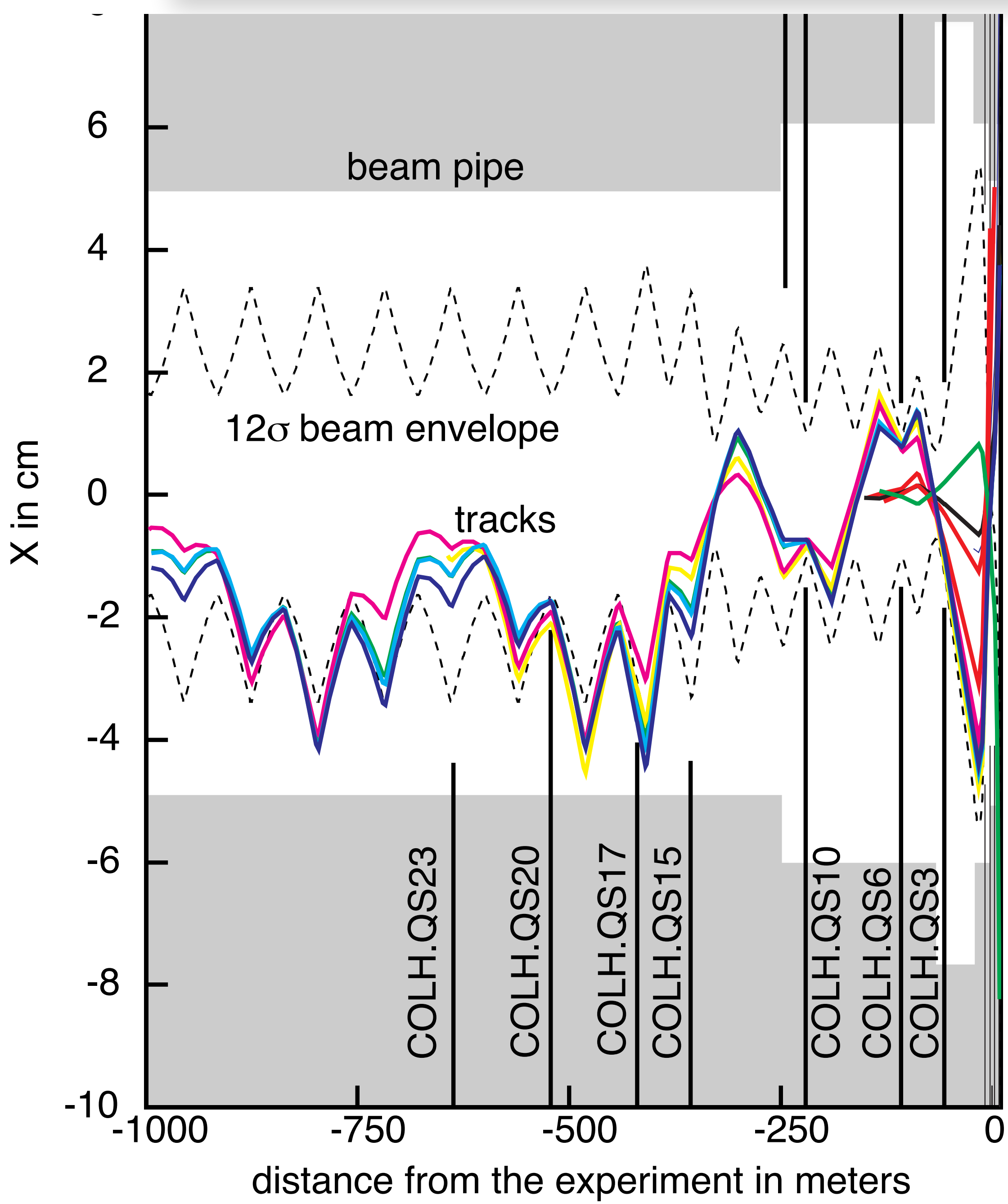


Illustration of beam particle tracking through the LEP lattice over 1000 meters up to an experimental region (cs coordinates).
The distance X from the nominal orbit is given in cm units.
The tracks are for particles that are lost within ±9 m from the interaction point.
The 12σ beam envelope is shown as broken line.
The physical aperture limitation given by the beam pipes is shaded.
The position of collimators (called COLH.QS15, COLH.QS17..) as used in LEP physics runs is shown as vertical straight lines.

LEP had ~ 100 collimators + IPs with local masks, r = 50 mm beam pipe at IP
plot from my simulation for the [1998 LEP background NIM paper]