EPAC 06

Non-Linear Collimation in Linear and Circular Colliders

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Outline

- Introduction
- Why nonlinear collimation?
- State of the art
- System equations
  - Linear Colliders
  - Circular Colliders
- Nonlinear Energy Collimation for CLIC
- Nonlinear Betatron Collimation for LHC

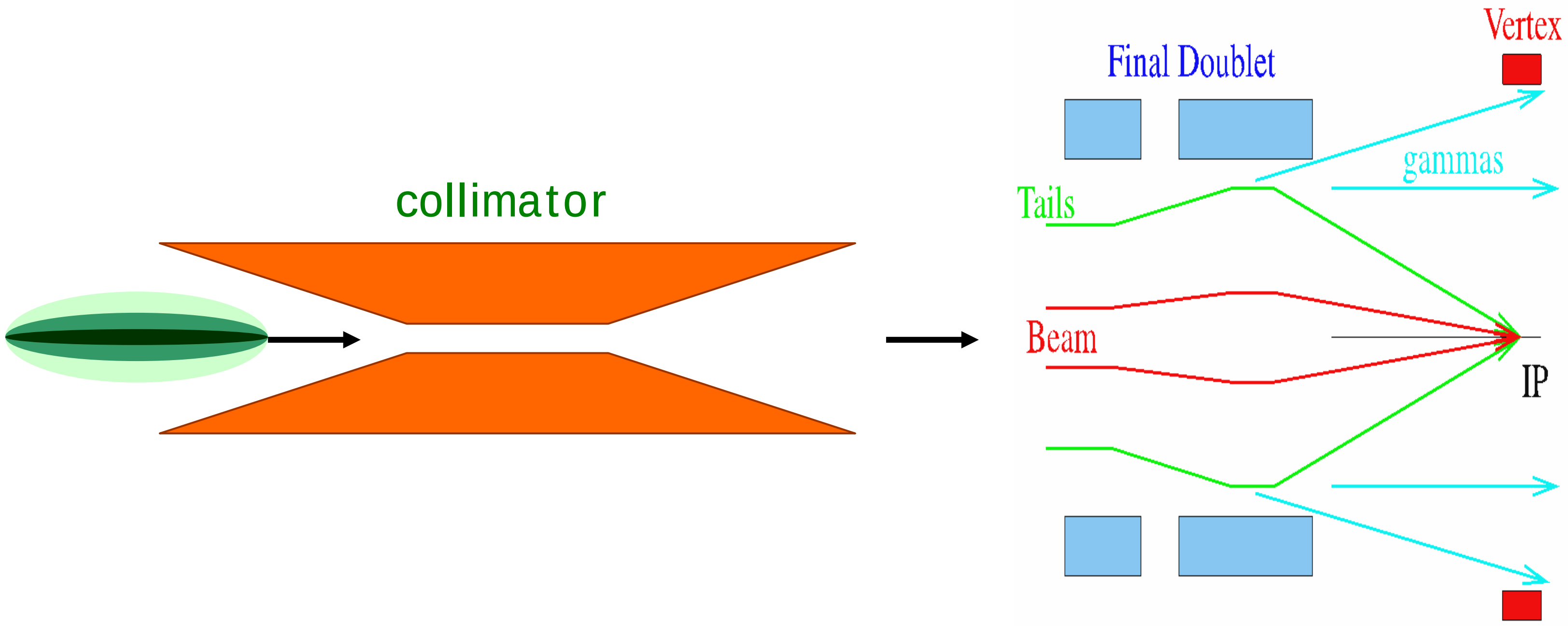
The role:

The collimation system of a L/C C must serve multiple purposes and fulfill a number of constraints.

- reduce the background in the particle detector by removing particles at large betatron amplitudes or energy offsets,
- withstand the impact of a full bunch train in case of machine failure
- minimize the activation of accelerator components outside of the dedicated collimation insertion
- not produce intolerable wake fields that might compromise beam stability

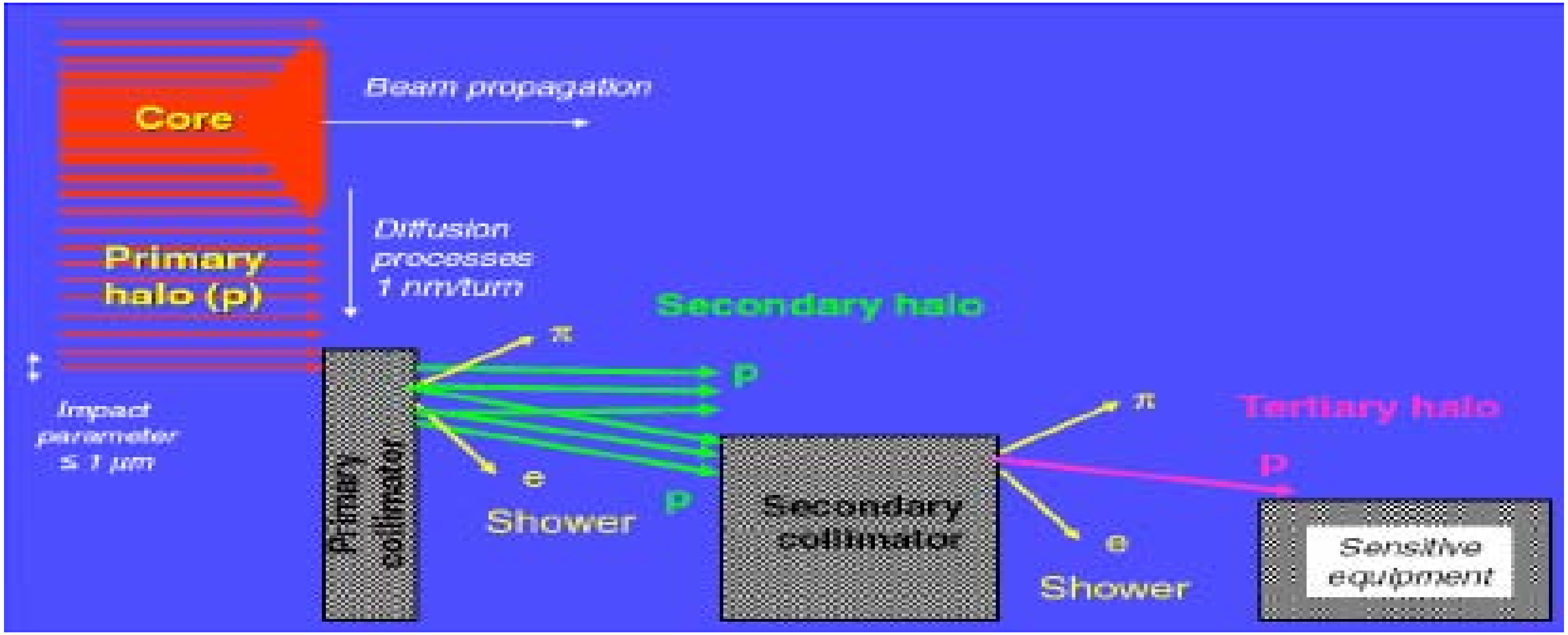
The motivation for LC:

to blow-up the beam size and to reduce the length taking advantage of $\beta\varepsilon << D_x\delta$.



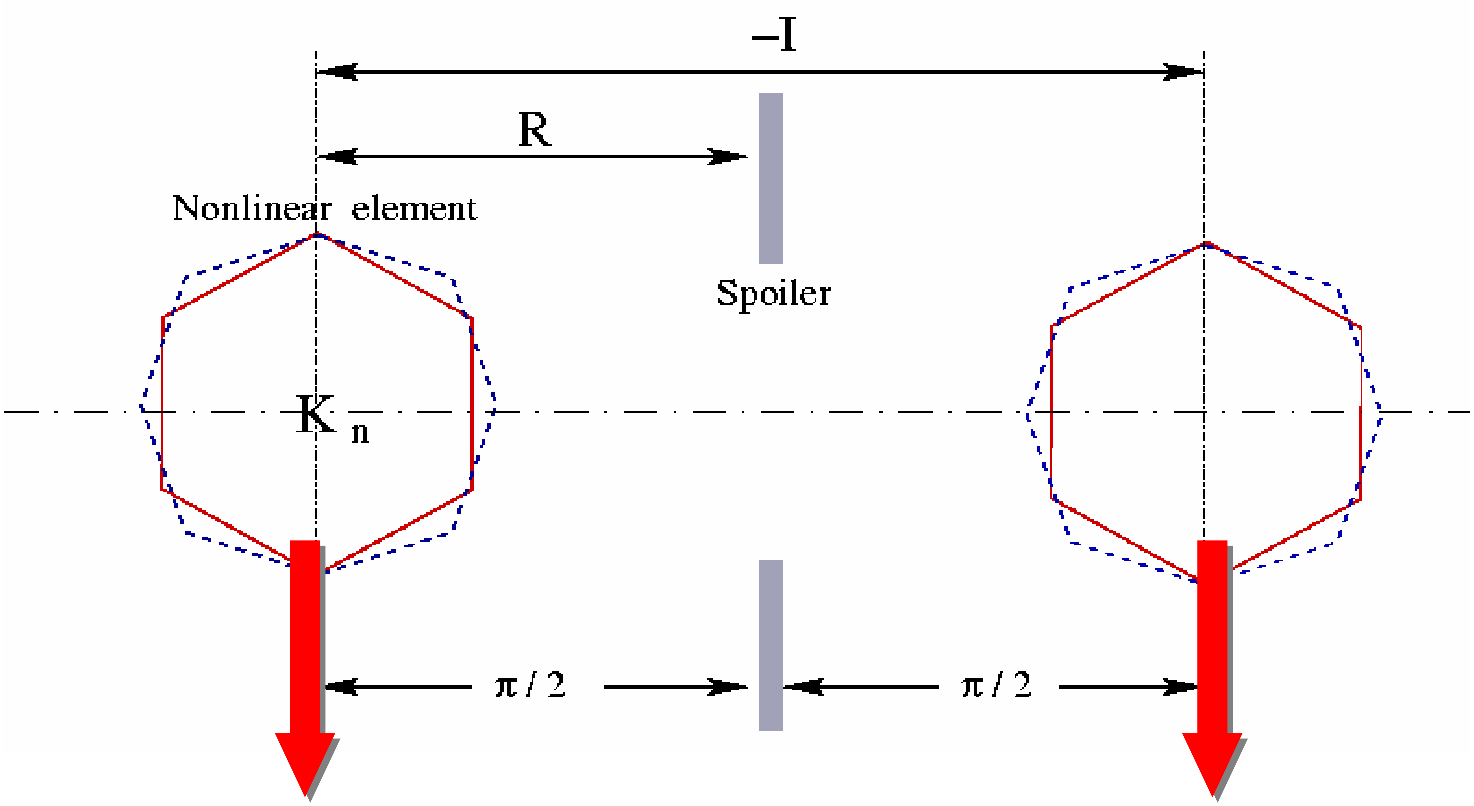
The motivation for CC:

reduction of resistive impedance because of the larger aperture of the spoiler. In this situation $\beta\varepsilon >> D_x\delta$ and there is no need of a large blow-up of beam sizes.



The Basic Scheme:

Deflection at the nonlinear element $\Delta q_i' = -\partial H_n / \partial q_i$

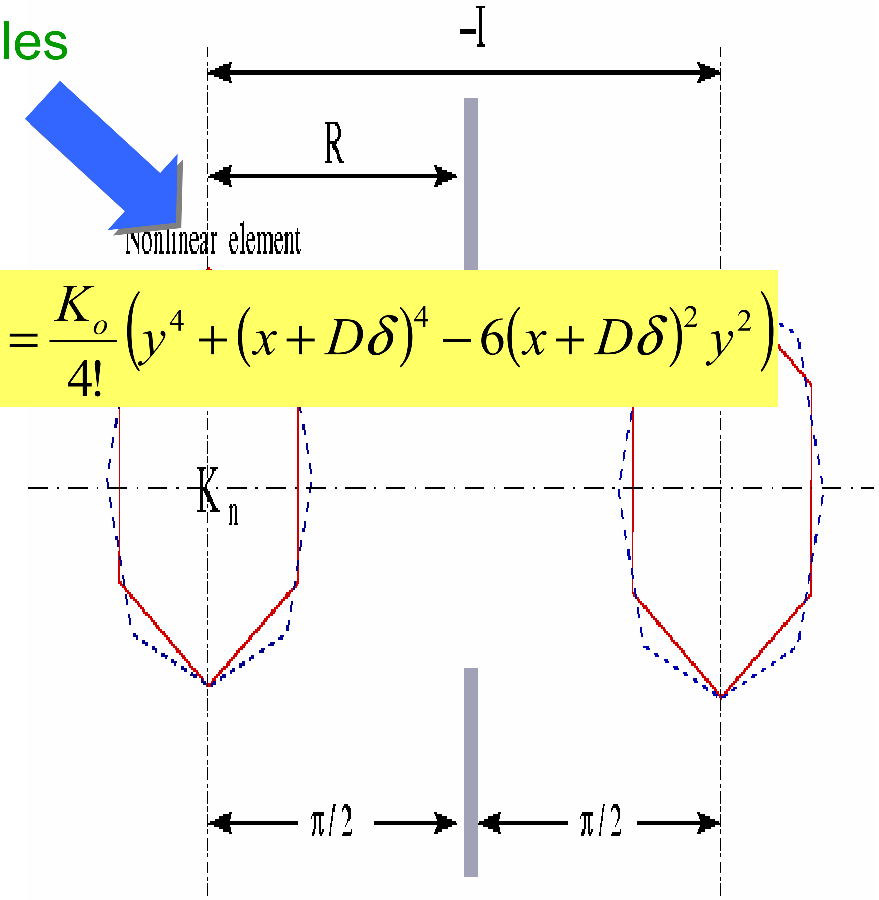


increase beam size at the spoilers **cancel aberrations**

The Basic Scheme:

- Nonlinear elements used are:
  skew sextupoles and octupoles

$$H_s = \frac{K_s}{3!}\left(y^3 - 3(x + D\delta)^2 y\right)$$



$$H_o = \frac{K_o}{4!}\left(y^4 + (x + D\delta)^4 - 6(x + D\delta)^2 y^2\right)$$

- Higher-order multipoles (decapoles, dodecapoles, …), are not useful because they don´t penetrate to the small distances needed

  [N. Merminga et al., SLAC-PUB-5165 Rev. May 1994]

The state of the art:

- Scheme with skew-sextupole pairs in NLC for nonlinear betatron collimation in the vertical plane

  [N. Merminga, J. Irwin, R. Helm and R. Ruth, SLAC PUB 5165 Rev. (1994)]

- "Tail folding" octupoles in the NLC final focus system

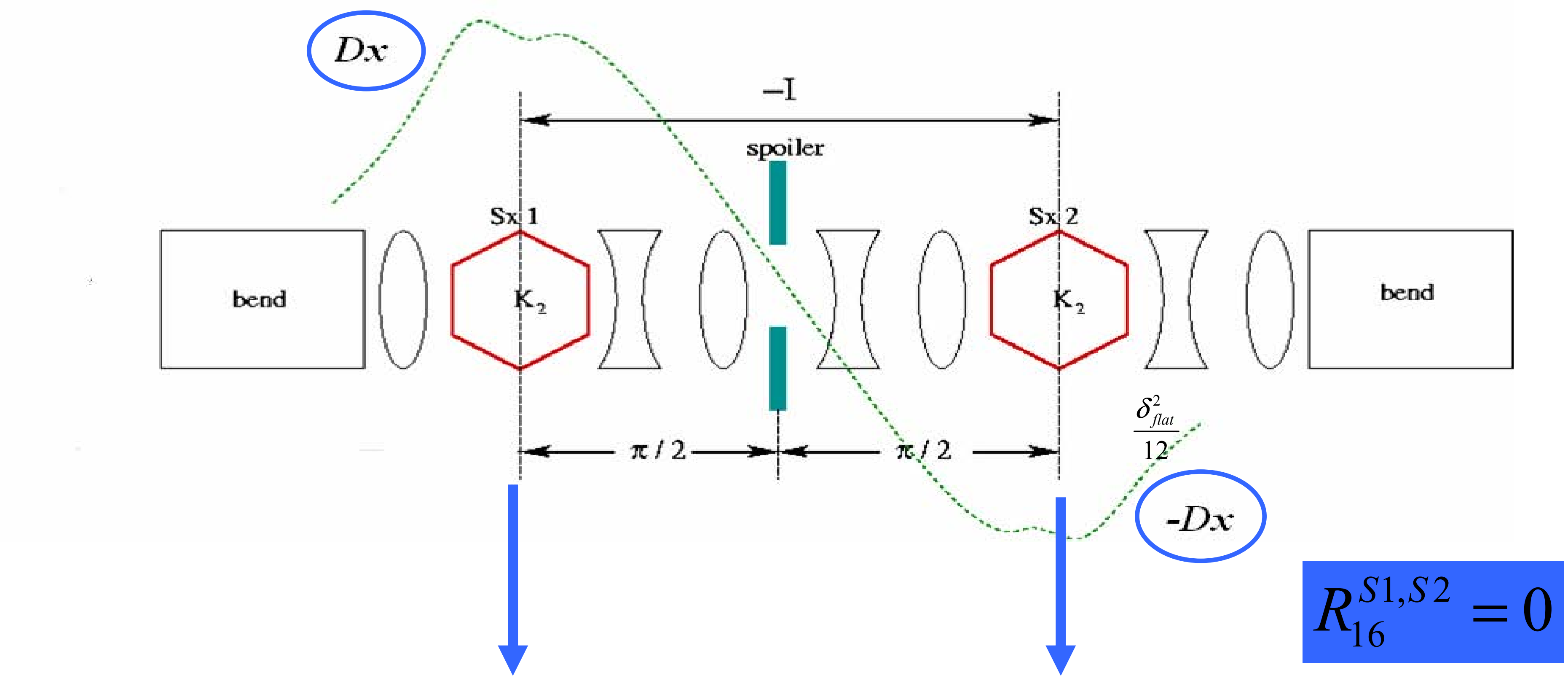
  [R. Brinkmann, P. Raimondi and A. Seryi, PAC2001, PAC 2001 Chicago]

- A magnetic energy spoiler (MES) for the TESLA post-linac collimation system

  [R. Brinkmann, N. J. Walker and G. Blair, DESY TESLA-01-12 (2001)]

- Scheme with three skew sextupoles for CLIC
  [A. Faus-Golfe and F. Zimmermann, EPAC 2002, Paris]

The nonlinear collimation system:



$$R_{16}^{S1,S2} = 0$$

increase σ_y at spoiler

cancels the geometric and 1st order chromatic aberrations

The system equations:

relative momentum offset

$$\delta$$

The Hamiltonian:

$$H_{sext} = \frac{K_s}{3!}\left(y^3 - 3\left(x + D_{x,sext}\,\delta\right)^2 y\right)$$

$$K_s = \frac{2B_T l_s}{(B\rho)a_s^2}$$

Integrated sextupole strength

The deflection:

$$\Delta x' = -\frac{\partial H_{sext}}{\partial x} = K_s\left(x + D_{x,sext}\,\delta\right)y$$

$$\Delta y' = -\frac{\partial H_s}{\partial y} = -\frac{1}{2}K_s\left(y^2 - x^2 - D^2_{x,sext}\,\delta^2 - 2D_{x,sext}\,\delta x\right)$$

The system equations:

Position at the downstream spoiler:

$$x_{sp} = x_{0,sp} + R_{12}^{sext,sp} \Delta x'$$

$$y_{sp} = y_{0,sp} + R_{34}^{sext,sp} \Delta y'$$

optical transport matrix between sextupole and spoiler

position at the downstream spoiler w/o skew sextupole

$$x_{0,sp} = x_{\beta,sp} + D_{x,sp} \delta$$

$$y_{0,sp} = y_{\beta,sp}$$

The system equations:

Transverse beam size at the downstream spoiler:

$$\sigma_{x,sp} = \sqrt{\left\langle x_{sp}^2 \right\rangle - \left\langle x_{sp} \right\rangle^2}$$

$$\sigma_{y,sp} = \sqrt{\left\langle y_{sp}^2 \right\rangle - \left\langle y_{sp} \right\rangle^2}$$

for spoiler survival:

$$\sigma_{r,\min} = \sqrt{\sigma_{x,sp}\,\sigma_{y,sp}}$$

this value depends on the spoiler material and determines the minimum value of Ks, R_{12} and R_{34}

The system equations for LC:

Assuming $\beta\varepsilon << D_x\delta$ both at the spoiler and the sextupoles and flat beams $x_\beta >> y_\beta$:

Gaussian momentum distribution:

$$P(\delta) = \frac{1}{\sqrt{2\pi}\sigma_\delta} e^{-\frac{1}{2}\left(\frac{\delta+\delta_0}{\sigma_\delta}\right)^2}$$

δ_0 average momentum offset

The beam size at the spoiler:

$$\sigma_{x,sp} \approx \sqrt{D_{x,sp}^2\sigma_\delta^2 + R_{12}^2 K_s^2 D_{x,sext}^2\left(\delta_0^2+\sigma_\delta^2\right)\beta_{y,sext}\varepsilon_y}$$

$$\sigma_{y,sp} \approx \sqrt{\frac{1}{2}R_{34}^2 K_s^2 D_{x,sext}^4\left(\sigma_\delta^4 + 2\delta_0^2\sigma_\delta^2\right)}$$

The system equations for LC:

Uniform flat momentum distribution:

δ_0 average momentum offset

$$P(\delta) = \begin{cases} 0 & \delta < -\frac{\delta_{flat}}{2} + \delta_0 \\ \frac{1}{\delta_{flat}} & -\frac{\delta_{flat}}{2} + \delta_0 < \delta < \frac{\delta_{flat}}{2} + \delta_0 \\ 0 & \delta > \frac{\delta_{flat}}{2} + \delta_0 \end{cases}$$

The beam size at the spoiler:

$$\sigma_{x,sp} \approx \sqrt{D_{x,sp}^2 \frac{\delta_{flat}^2}{12} + R_{12}^2 K_s^2 D_{x,sext}^2 \left(\frac{\delta_{flat}^2}{12} + \delta_0^2 \right) \beta_{y,sext} \varepsilon_y}$$

$$\sigma_{y,sp} \approx \sqrt{\frac{1}{4} R_{34}^2 K_s^2 D_{x,sext}^4 \left(\frac{\delta_{flat}^4}{180} + \frac{1}{3} \delta_{flat}^2 \delta_0^2 \right)}$$

The system equations for LC:

Using a vertical spoiler the nonlinear terms in the sextupolar deflection also yields a collimation for horizontal or vertical amplitudes at collimation depth (units of $\sigma_{x,y}$) of:

$$n_x = \frac{D_{x,sext}\Delta}{\sqrt{\beta_{x,sext}\varepsilon_x}}, n_y = \frac{D_{x,sext}\Delta}{\sqrt{\beta_{y,sext}\varepsilon_x}}$$

Additionally we can collimate (in the other betatron phase) using the linear optics:

$$n_{x2} = \frac{a_x}{\sqrt{\beta_{x,sp}\varepsilon_x}} \approx \frac{D_{x,sp}\Delta}{\sqrt{\beta_{x,spo}\varepsilon_x}}$$

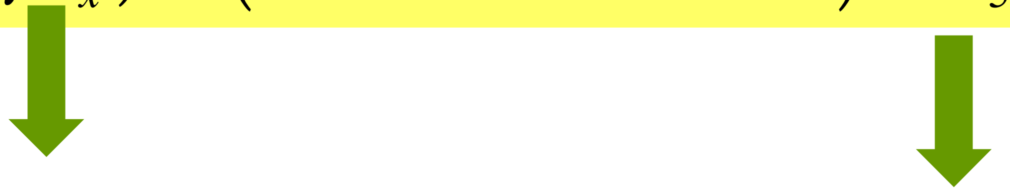
$$n_{y2} = \frac{a_y}{\sqrt{\beta_{y,sp}\varepsilon_y}} \approx \frac{1}{2}\frac{K_s R_{34} D^2_{x,sext}\Delta^2}{\sqrt{\beta_{y,sp}\varepsilon_y}}$$

spoiler half gaps

The system equations for LC:

The achievable value of $D_{x,sext}$ is limited by the emittance growth $\Delta(\gamma\varepsilon_x)$ due to SR in the dipole magnets:

$$\Delta(\gamma\varepsilon_x) \approx \left(4\times10^{-8}\,m^2 GeV^{-6}\right)E^6 I_5 < f\varepsilon_x$$



7%

1.0 x 10^{-19} m

f: fraction of the initial emittance

I_5: radiation integral

The system equations for CC:

Assuming $\beta\varepsilon >> D_x\delta$ both at the spoiler and the sextupoles.

The transverse beam size at the spoiler:

$$\sigma_{x,sp} \approx \sqrt{R_{12}^2 K_s^2 \beta_{x,sext}\beta_{y,sext}\varepsilon_x\varepsilon_y + \beta_{x,sp}\varepsilon_x}$$

$$\sigma_{y,sp} \approx \sqrt{\frac{1}{2}R_{34}^2 K_s^2\left(\beta_{x,sext}^2\varepsilon_x^2 + \beta_{y,sext}^2\varepsilon_y^2\right) + \beta_{y,sp}\varepsilon_y}$$

The system equations for LC:

To collimate in either transverse plane we must have:

physical
transverse
apertures

$$n_{y2}\sqrt{\beta_{y,sp}\varepsilon_y} = \frac{1}{2}K_s R_{34} n_x^2 \beta_{x,sext}\varepsilon_x$$

$$n_{y2}\sqrt{\beta_{y,sp}\varepsilon_y} = \frac{1}{2}K_s R_{34} n_y^2 \beta_{y,sext}\varepsilon_y$$

collimation
amplitudes for
betatron
motion

A horizontal collimator at the same location at the vertical spoiler will intercept particles with simultaneously large in both transverse planes. Its half gap aperture can be set to:

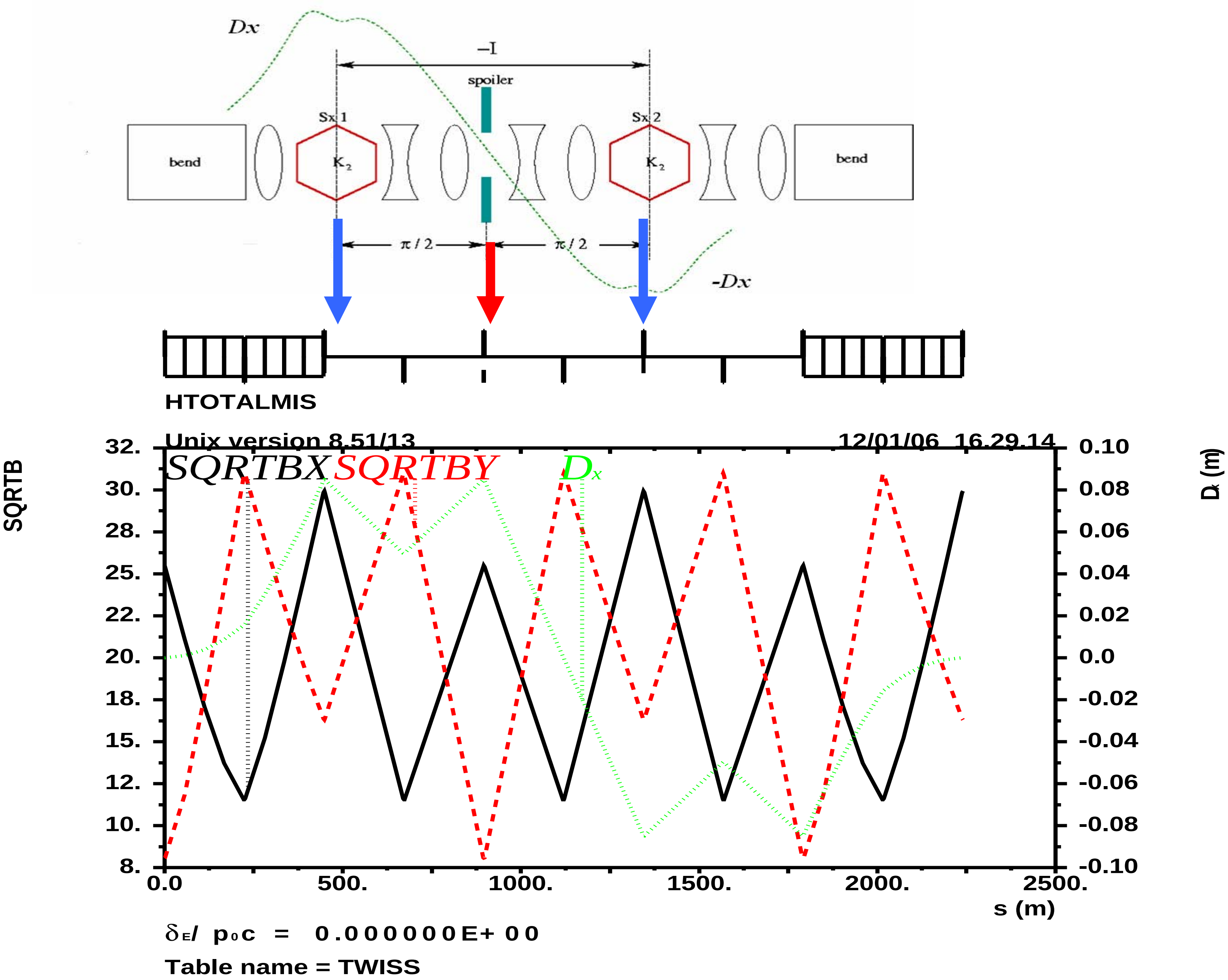
$$n_{x2}\sqrt{\beta_{x,sp}\varepsilon_x} = K_s R_{12} n_x n_y \sqrt{\beta_{x,sext}\varepsilon_y}\sqrt{\beta_{y,sext}\varepsilon_y}$$

Nonlinear energy collimation for CLIC

The changes respect to the previous optics designs:

- collimation only in energy
- maximize the overall fraction of the system occupied by bends and decreased the bending angle until SR became reasonably small. But no bends were installed between the skews $(R_{16}^{s1s2} = 0)$ to cancel the geometric and first order chromaticaberrations and the luminosity degradation
- keep β-functions as regular as possible to avoid the need of chromatic correction

The optics solution:



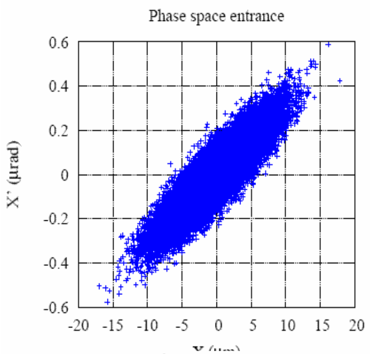
Performance from analytical studies:

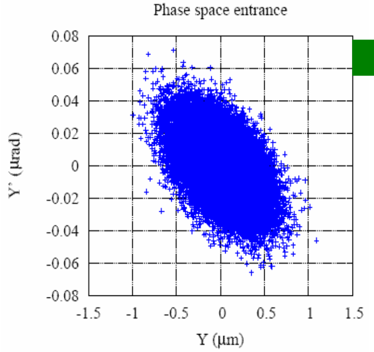
E	1.5	Tev
σ_ε	2.8 x 10^{-3}	
ε_x	0.23	pm
ε_y	6.8	fm
δ_{flat}	0.01	
L_t	2536	m
l_d	220	m
θ_b	0.00014	rad
K_s	20.9	m^{-2}
$\beta_x^{\ s}$	896.1	m
$\beta_y^{\ s}$	266.0	m
$\Delta\mu_{x,y}^{\ s,sp}$	0.25/0.25	2π
$\Delta\mu_{x,y}^{\ si,sf}$	0.5/0.5	2π
$R_{12}^{\ s,sp}$	763.2	m
$R_{34}^{\ s,sp}$	131.5	m
I_5	1.64 x 10^{-21}	
$\sigma_r^{\ sp}$	134.27	µm
Δ	0.013	
$a_x^{\ sp}$	1.103	mm
$a_y^{\ sp}$	1.669	mm

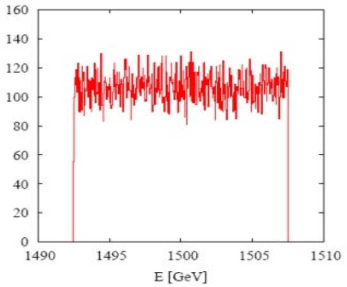
$\sigma_{r,min} \approx 120\ \mu m$

Tracking studies:

Entrance:







[J.Resta *et al*, CLIC Note 637]

Importance of the benchmarking of codes

Multiparticle tracking

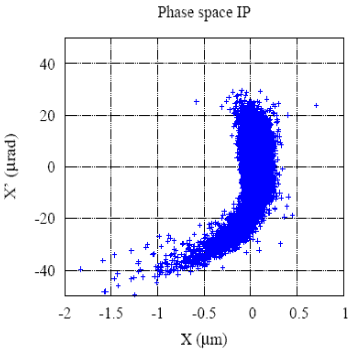
Optics lattice

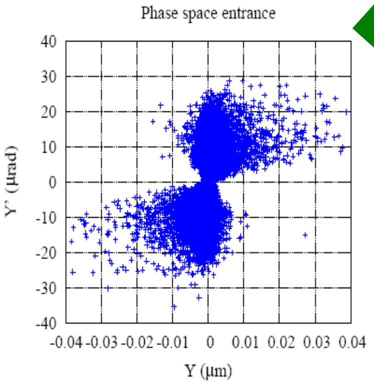
MAD
Placet
SAD

transport

Lie

IP:





spoiler:

Luminosity

beam-beam interaction

Guinea-Pig

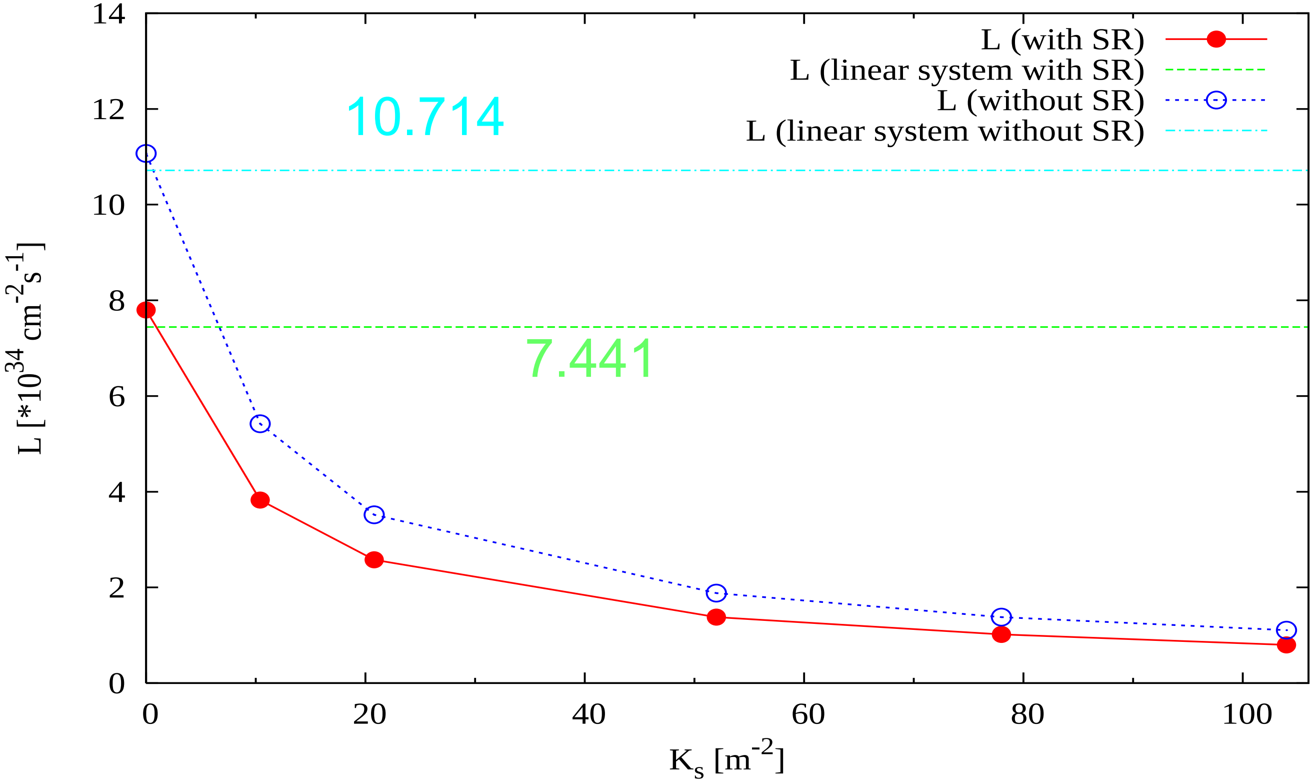
Off-line analysis

Peak density

Luminosity vs skew sextupole strength:

Tracking of a *uniform flat momentum distribution* of 40000 particles with 1% full width energy spread from the entrance of BDS to IP

Luminosity for optics lattice "NEW4.1"



Luminosity drops with the excitation of the skew sextupoles

Luminosity optimization:

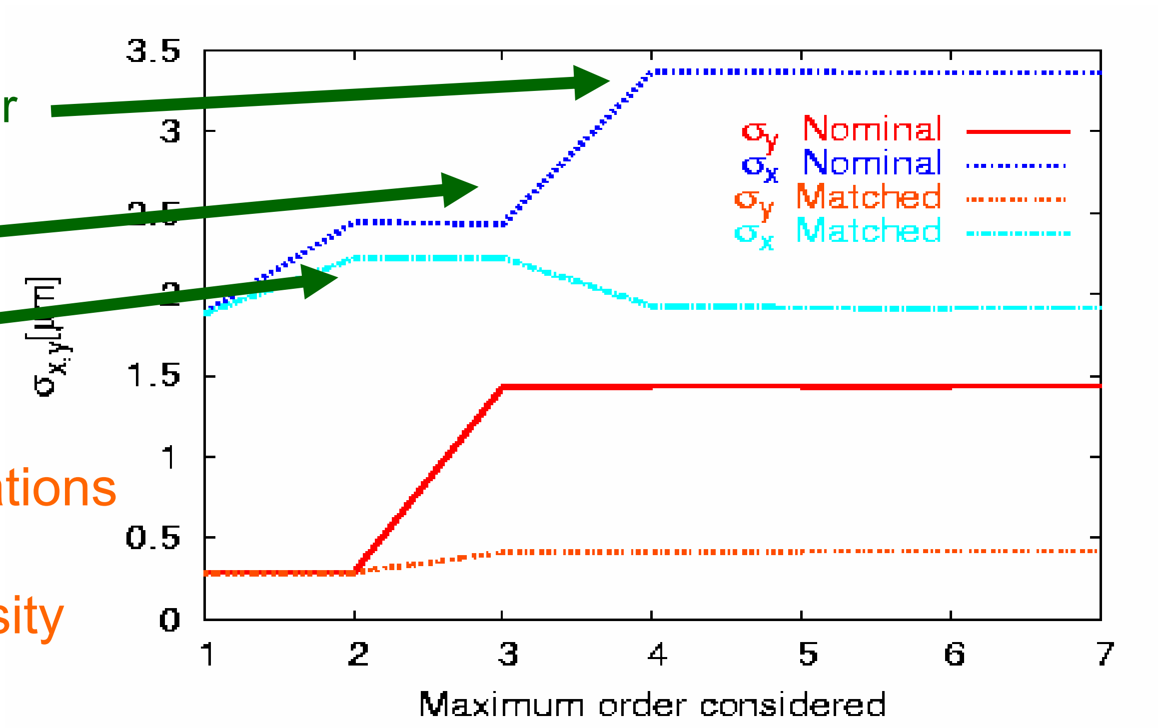
Optimization of the beam sizes with a MAPCLASS (Python code) by adding two additional multipoles (skew octupole and normal sextupole) for local cancellation of the higher order aberrations

[R. Tomás *et al*, EPAC'06 MOPLS100]

Fourth order

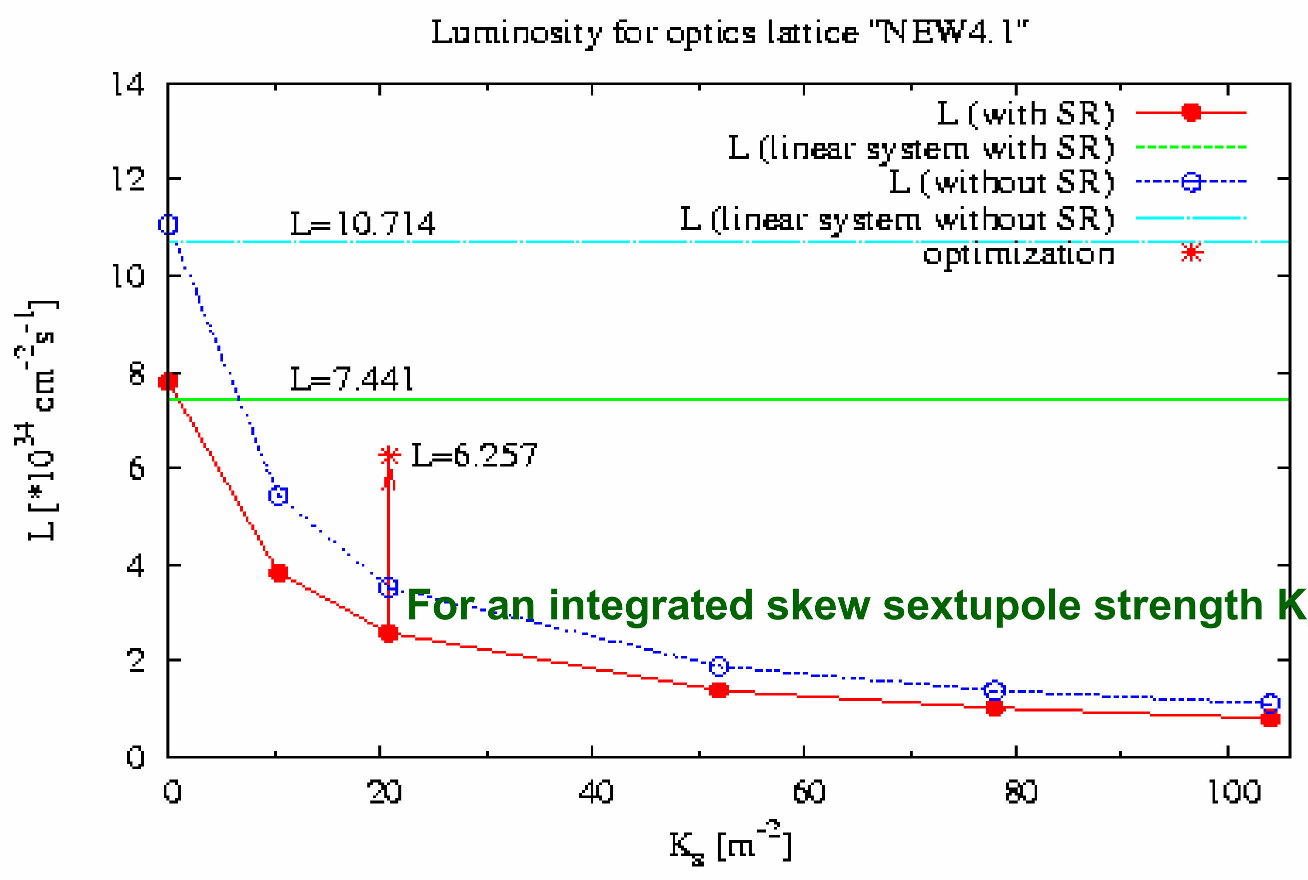
Third order

Second order



High chromatic aberrations of 2nd, 3rd and 4th are responsible of luminosity degradation

Optimized Luminosity:

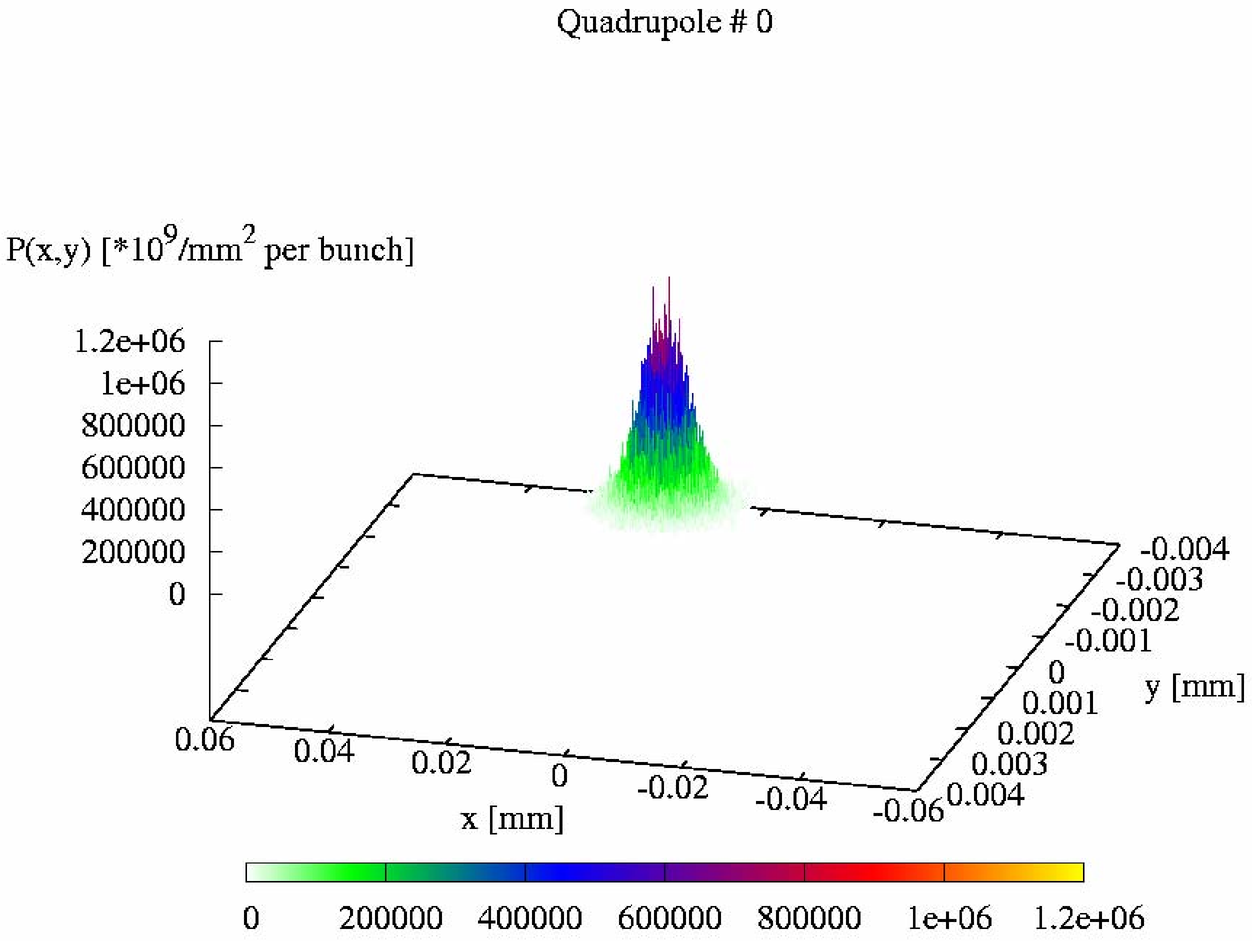


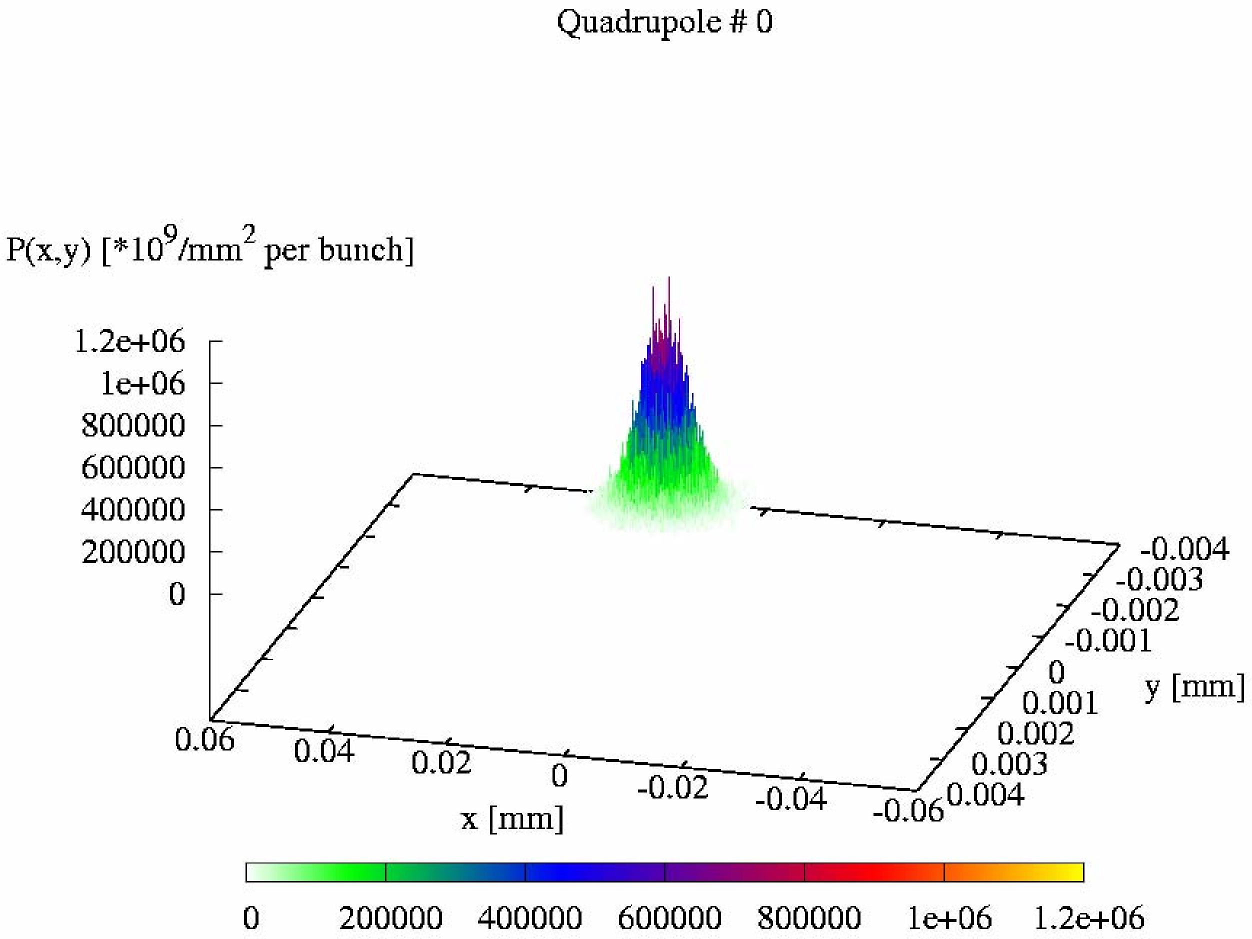
For an integrated skew sextupole strength K_s=20.86 m^{-2}

Luminosity is improved by more than a factor two

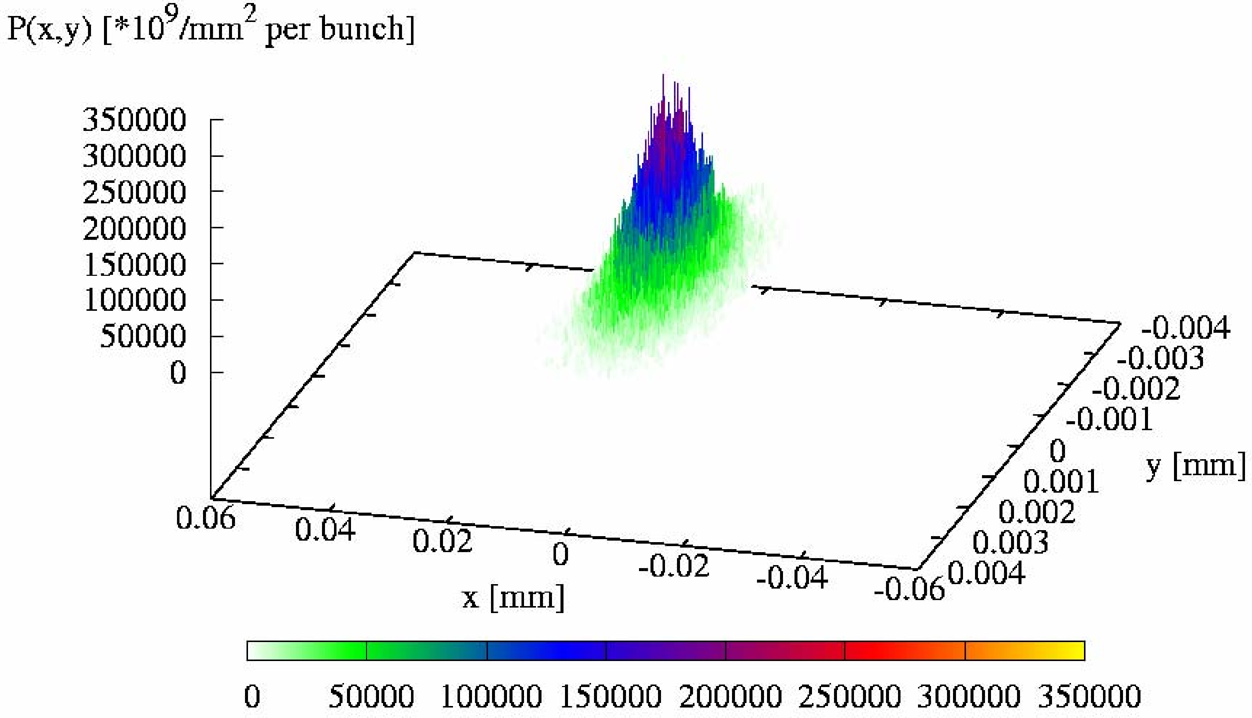
Beam profile:

Tracking of a *uniform flat momentum distribution* of 10000 particles with 3% full width energy spread from the entrance of BDS to spoiler

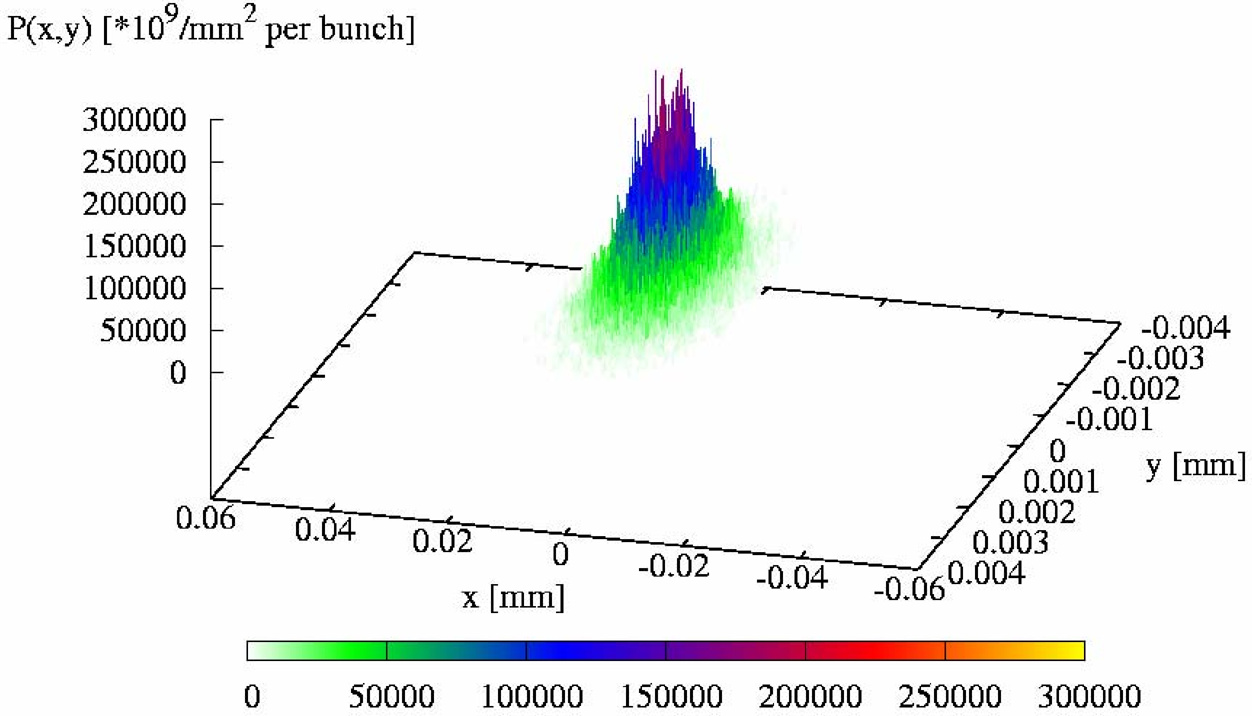



Quadrupole # 0
P(x,y) [*10^9/mm^2 per bunch]
1.2e+06
1e+06
800000
600000
400000
200000
0
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
x [mm]
-0.004
-0.003
-0.002
-0.001
0
0.001
0.002
0.003
0.004
y [mm]
0
200000
400000
600000
800000
1e+06
1.2e+06

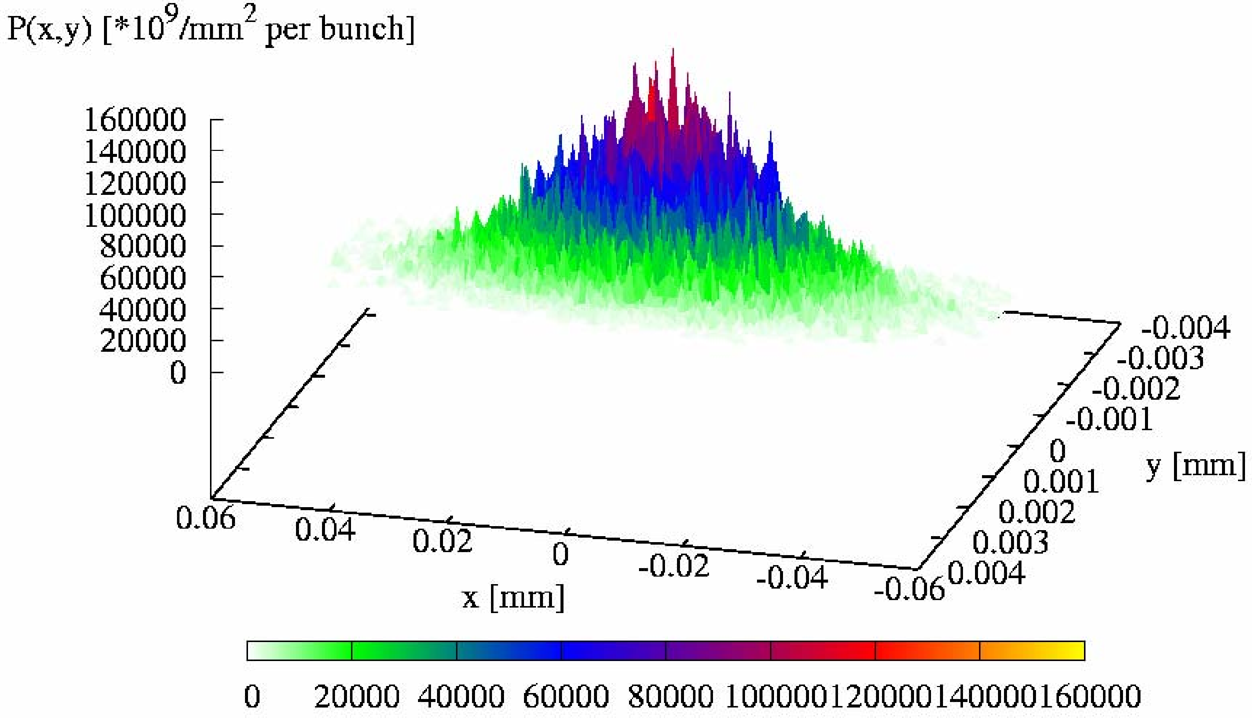
Quadrupole # 1



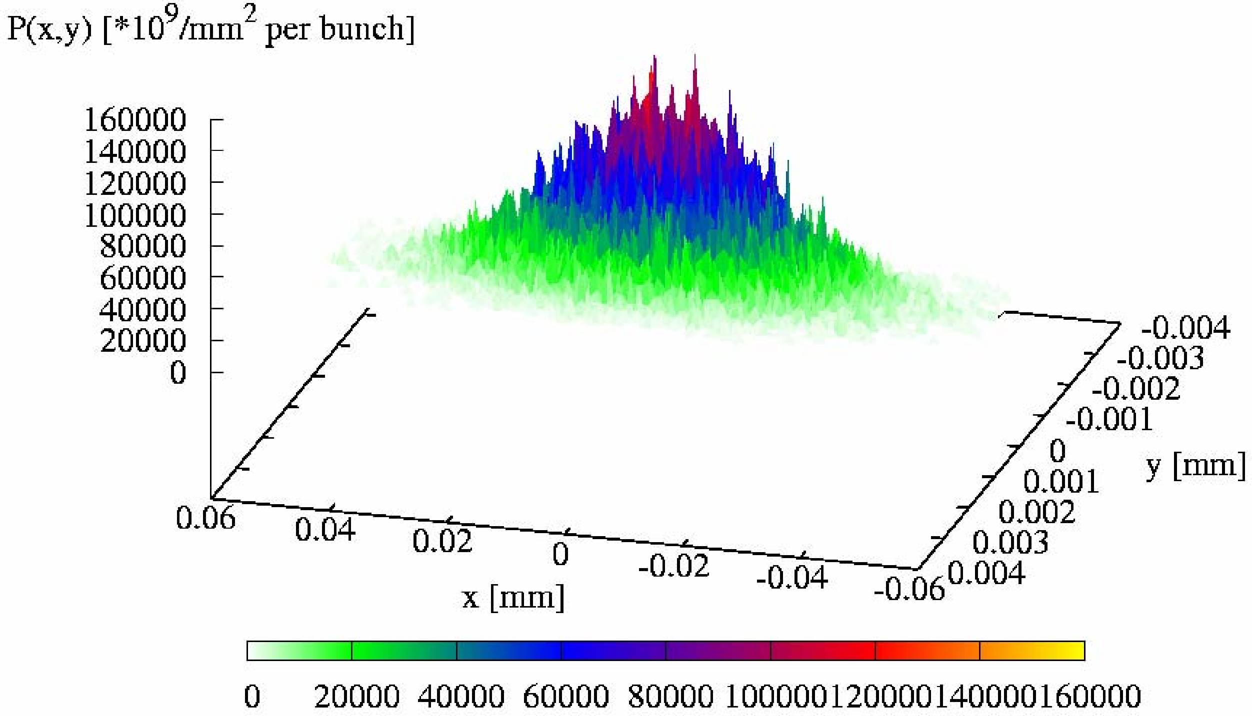
Quadrupole # 2

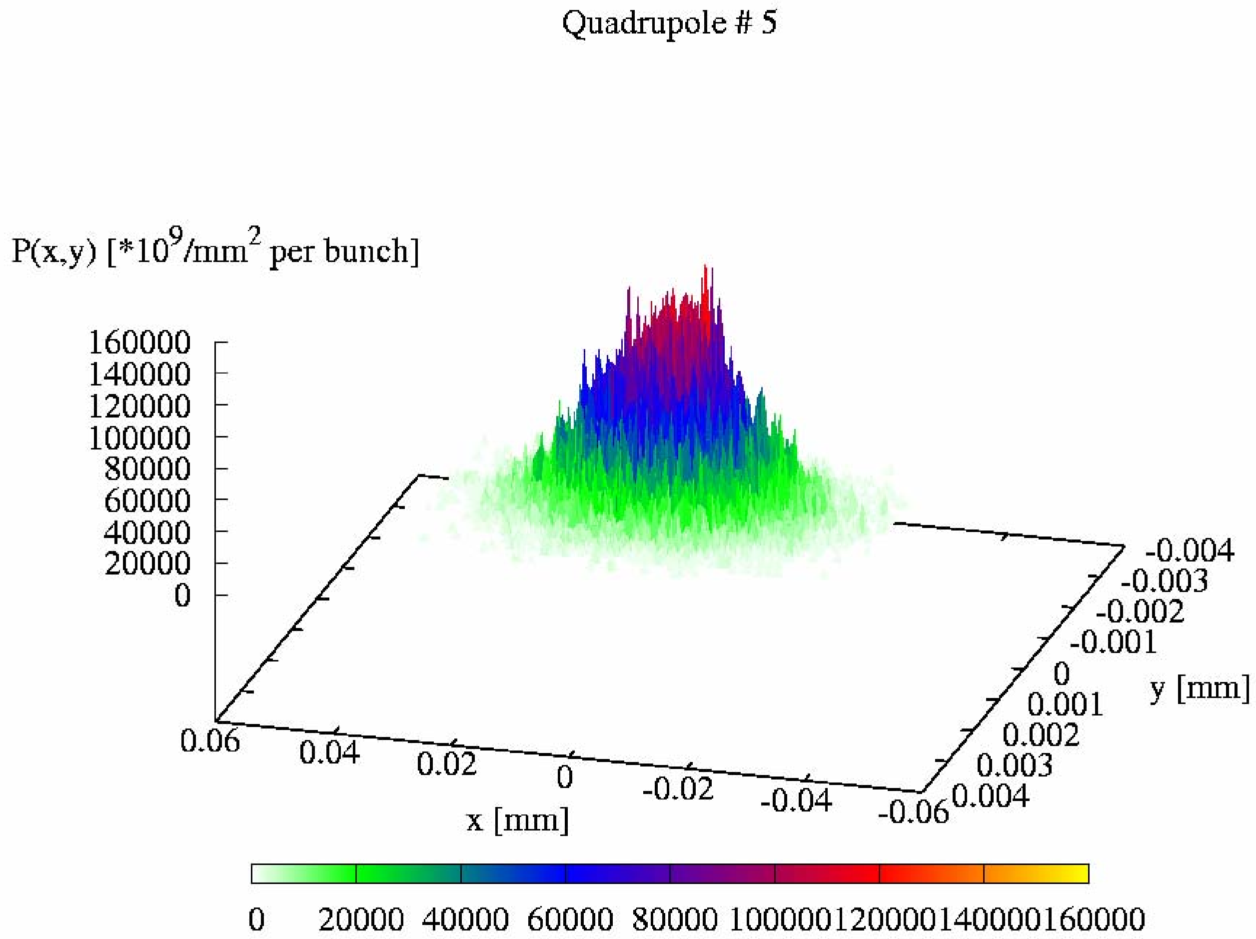


Quadrupole # 3

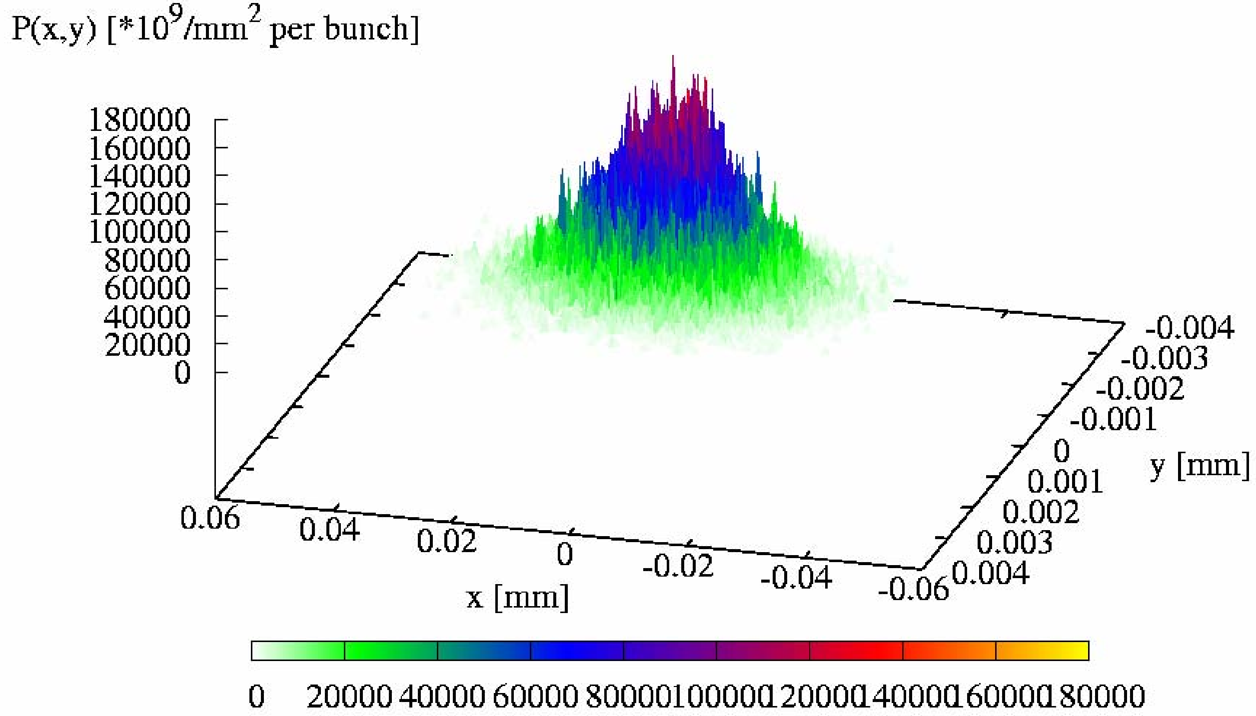


Quadrupole # 4

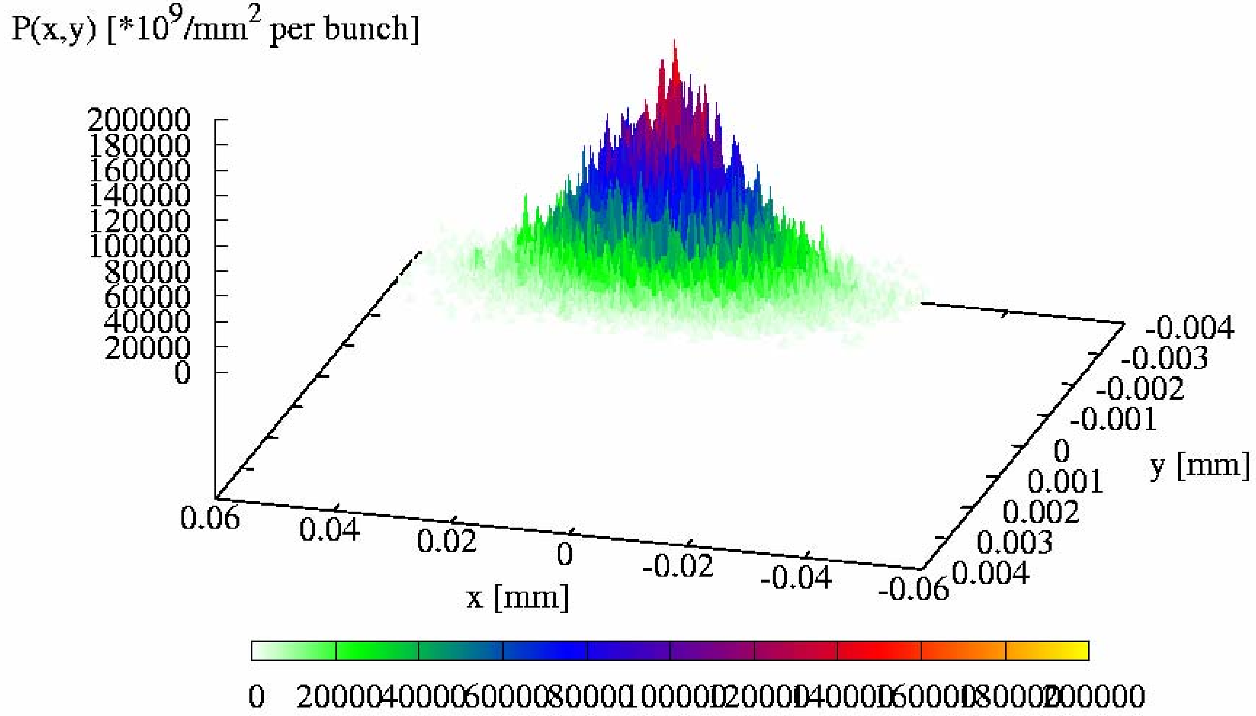


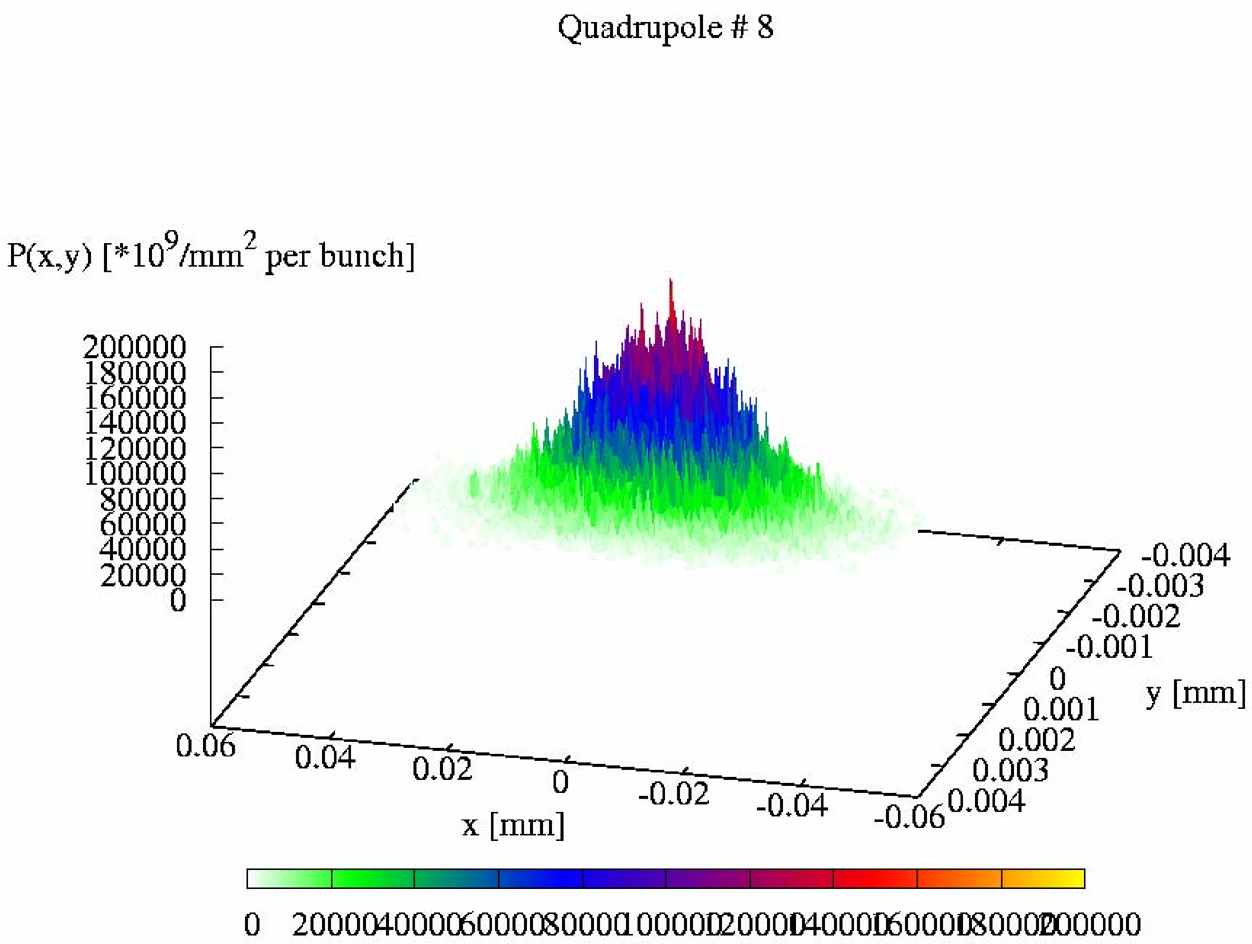

Quadrupole # 5
P(x,y) [*10^9/mm^2 per bunch]
160000
140000
120000
100000
80000
60000
40000
20000
0
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
x [mm]
-0.004
-0.003
-0.002
-0.001
0
0.001
0.002
0.003
0.004
y [mm]
0
20000
40000
60000
80000
100000
120000
140000
160000

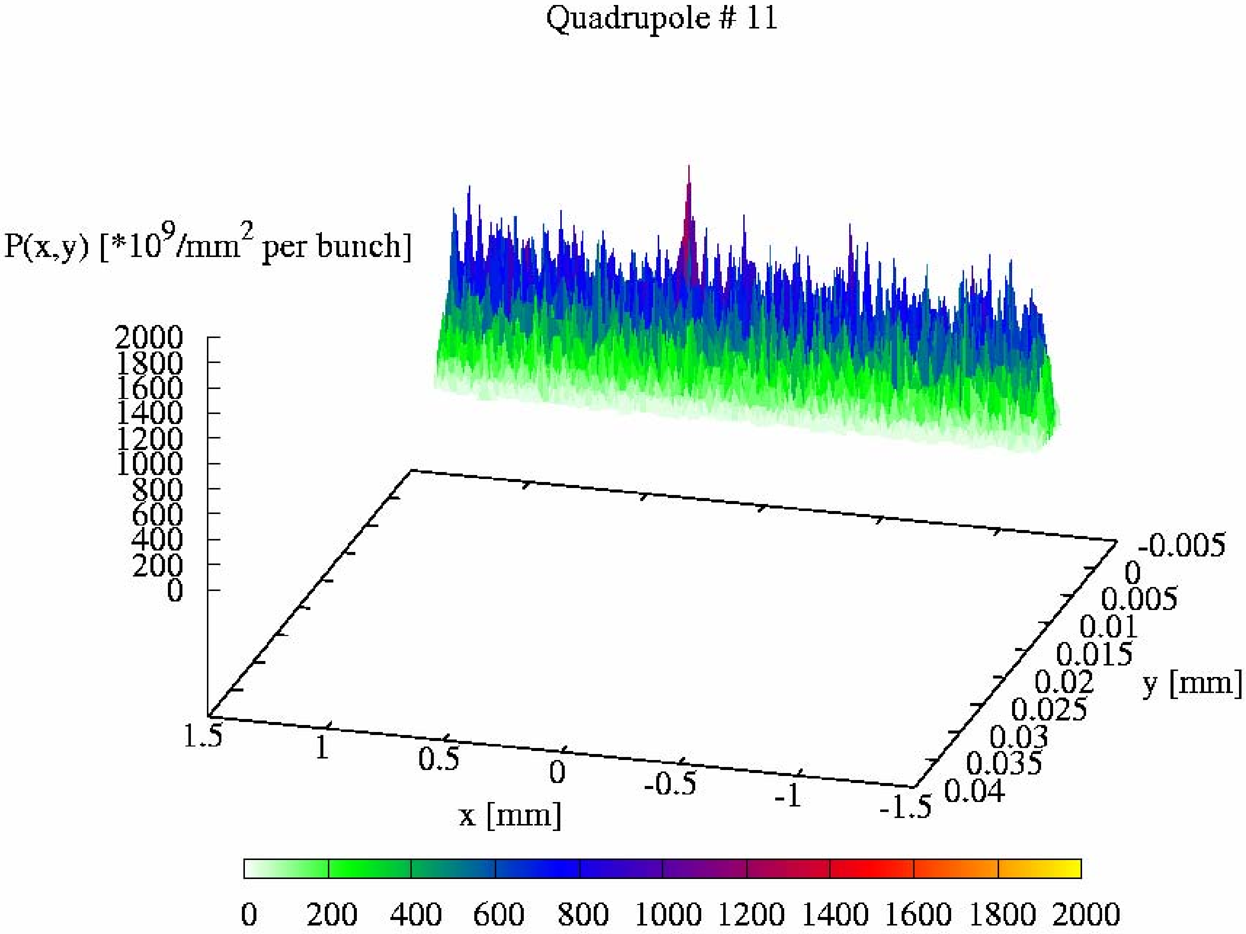
Quadrupole # 6

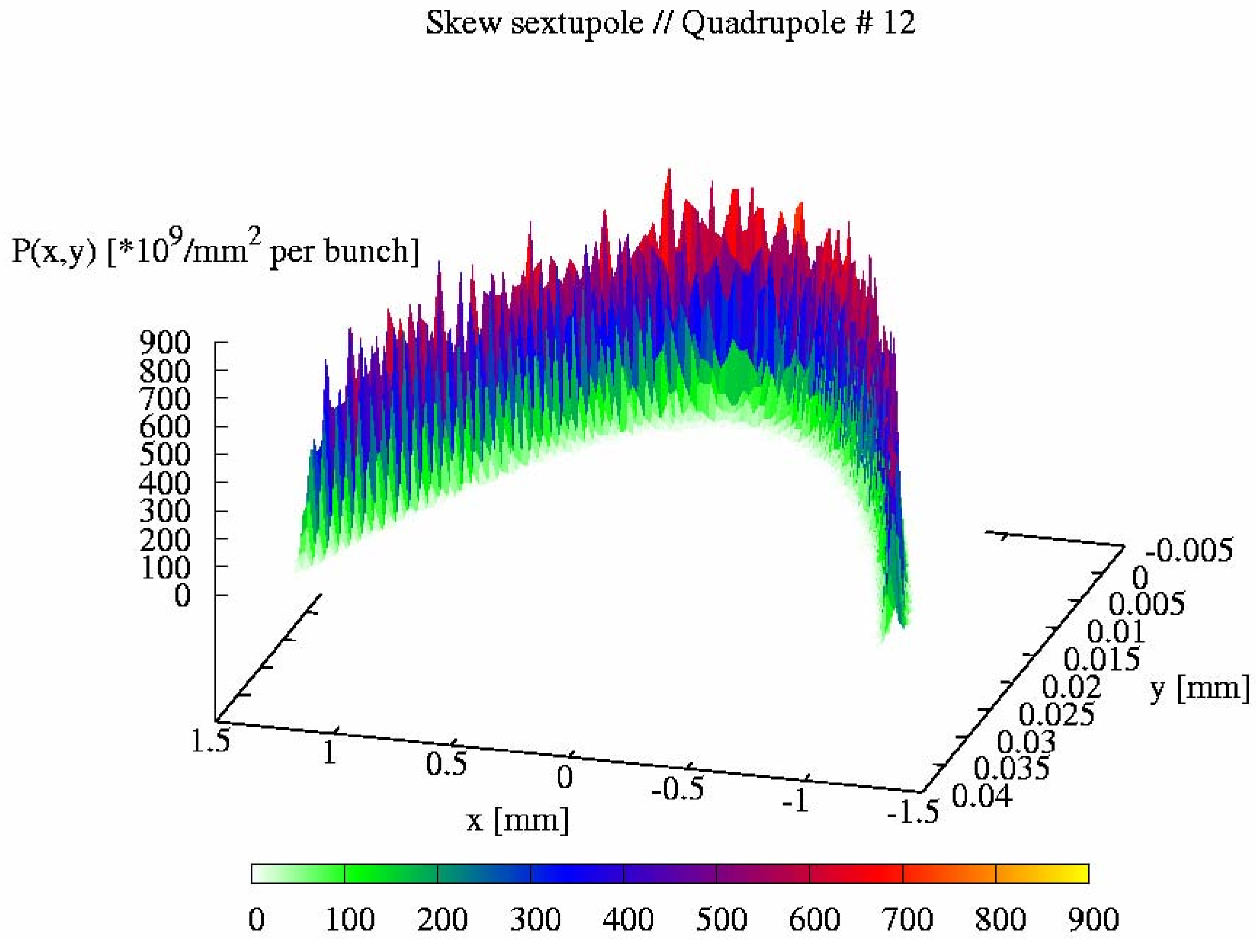


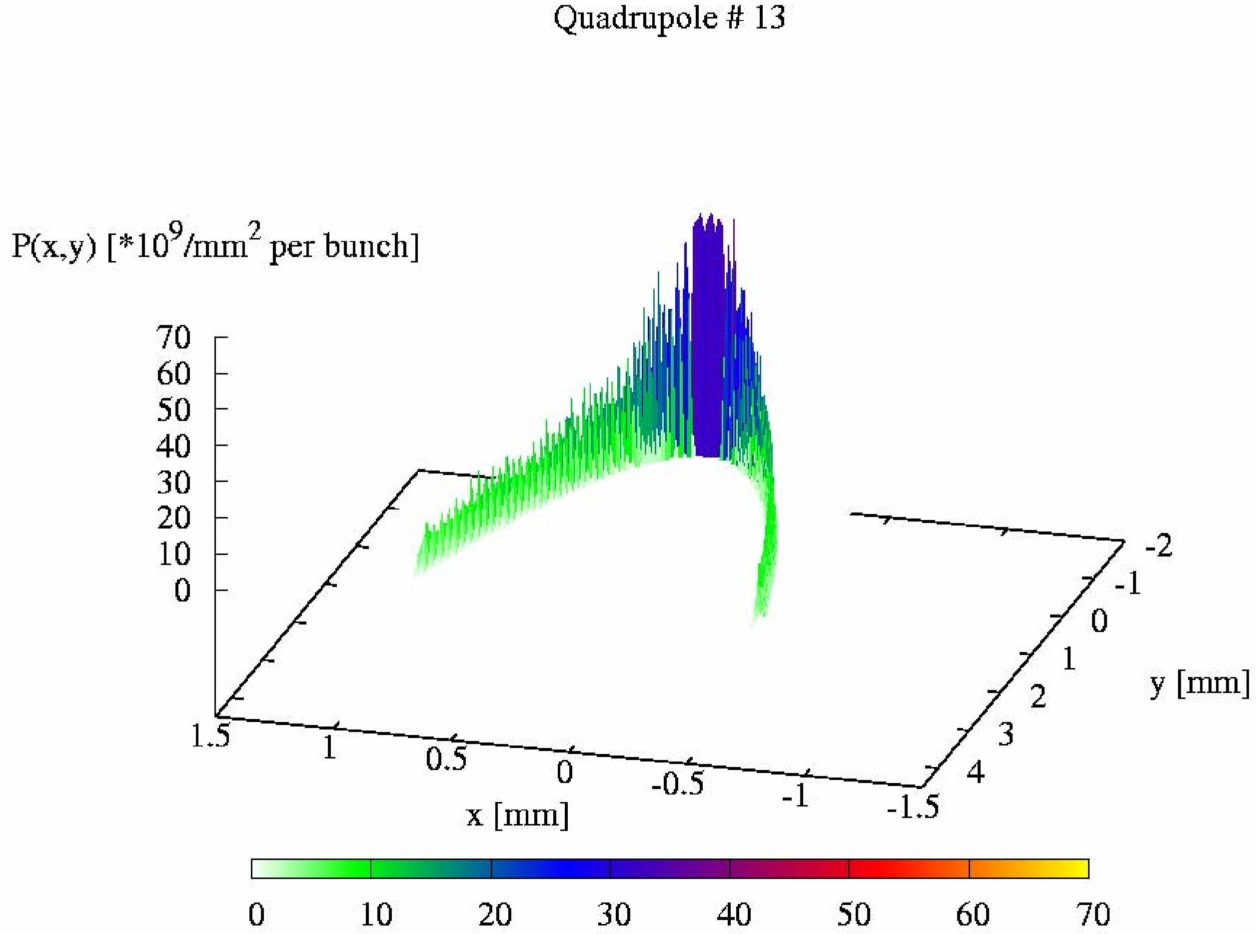
Quadrupole # 7

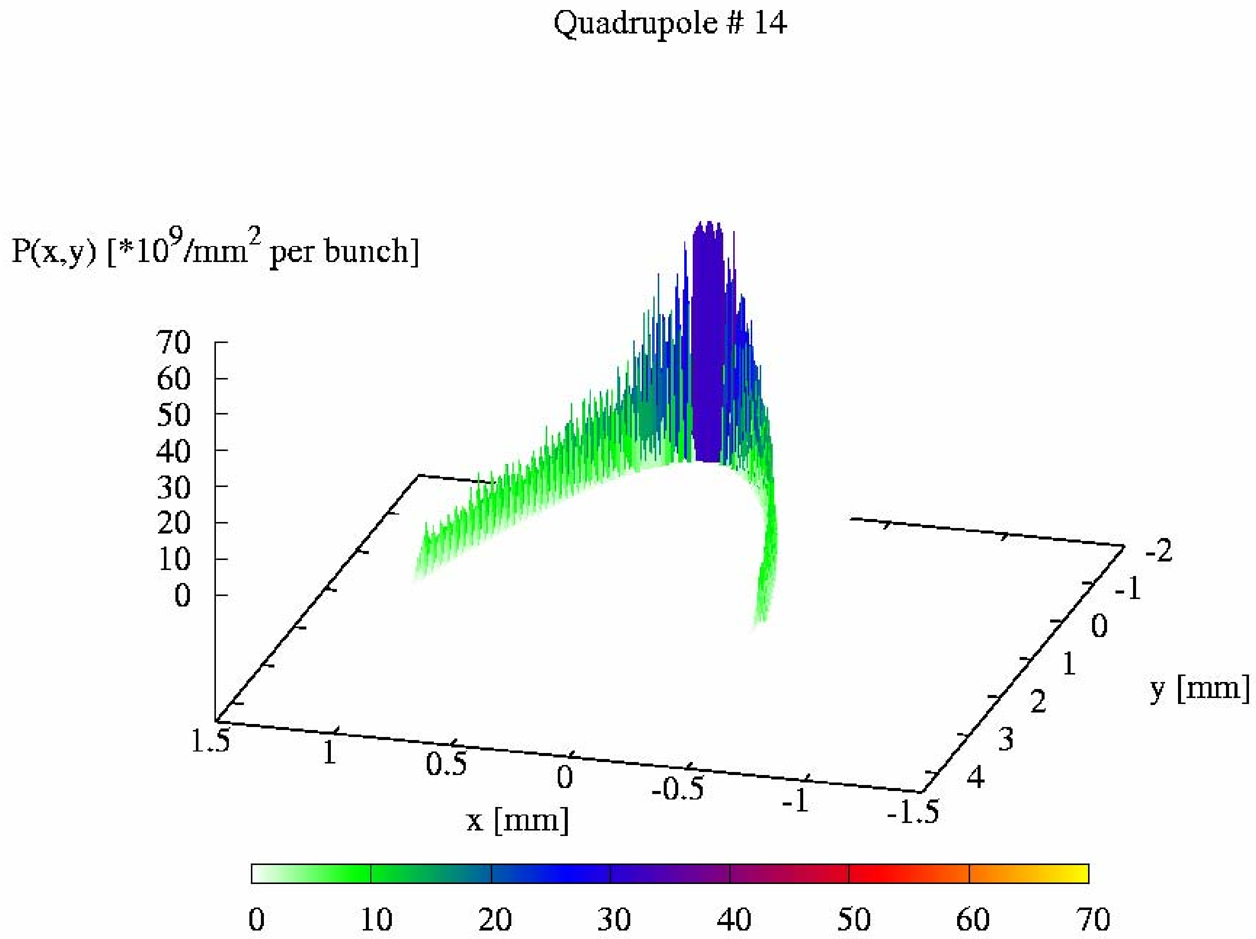


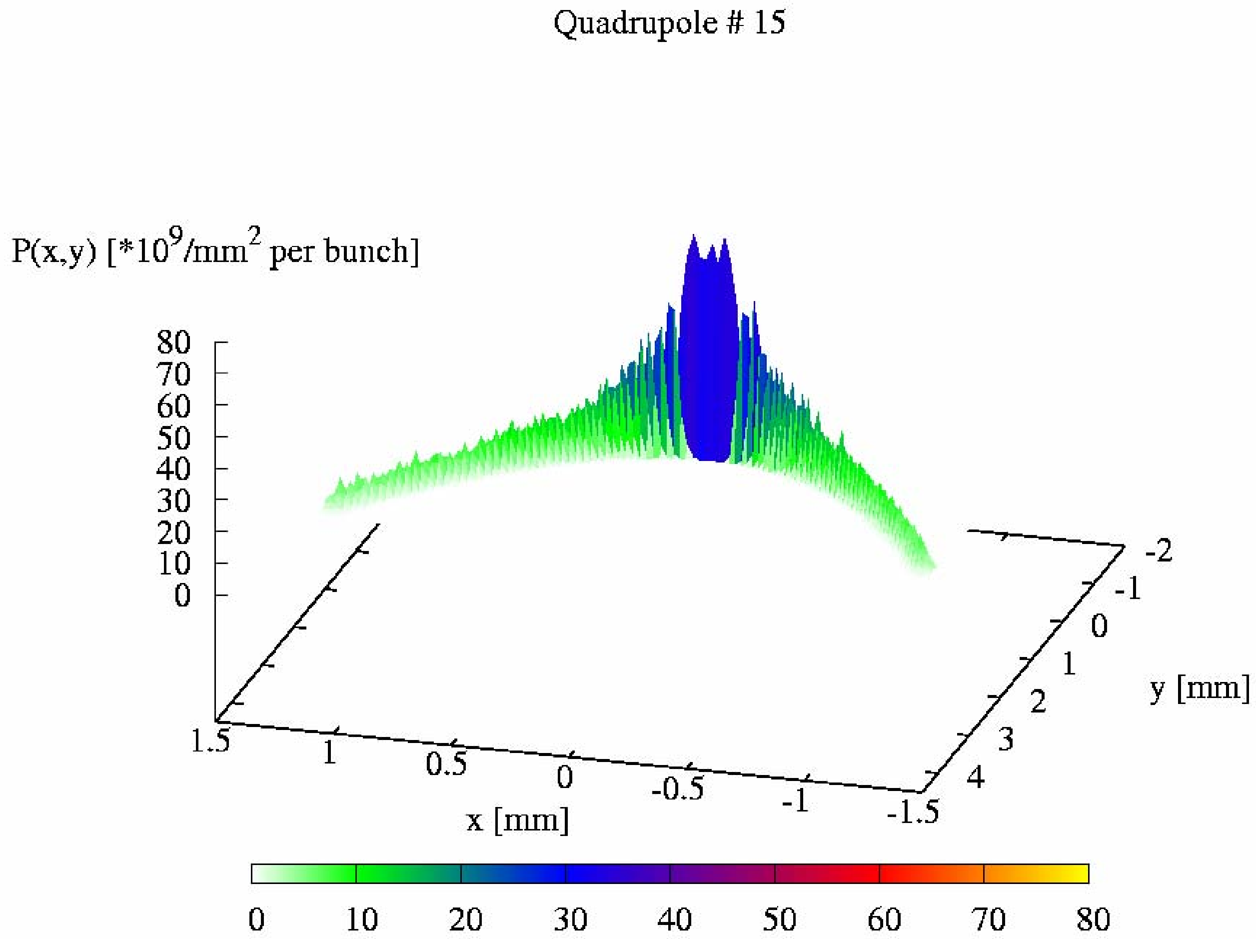

Quadrupole # 8
P(x,y) [*10^9/mm^2 per bunch]
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
x [mm]
-0.004
-0.003
-0.002
-0.001
0
0.001
0.002
0.003
0.004
y [mm]
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000

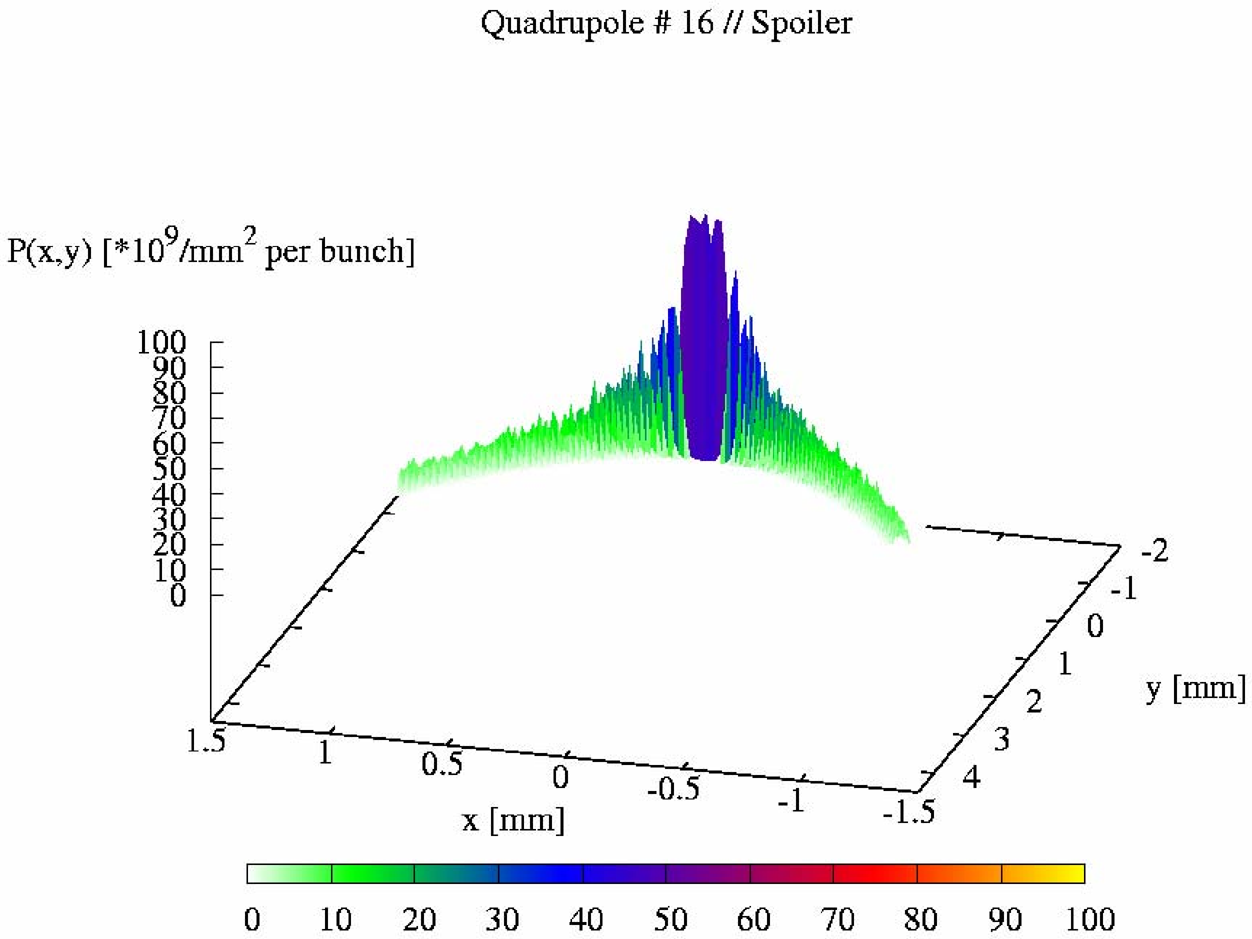

Quadrupole # 11
P(x,y) [*10^9/mm^2 per bunch]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1.5
1
0.5
0
-0.5
-1
-1.5
x [mm]
-0.005
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
y [mm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000


Skew sextupole // Quadrupole # 12
P(x,y) [*10^9/mm^2 per bunch]
900
800
700
600
500
400
300
200
100
0
1.5
1
0.5
0
-0.5
-1
-1.5
x [mm]
-0.005
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
y [mm]
0
100
200
300
400
500
600
700
800
900


Quadrupole # 13
P(x,y) [*10^9/mm^2 per bunch]
70
60
50
40
30
20
10
0
1.5
1
0.5
0
-0.5
-1
-1.5
x [mm]
-2
-1
0
1
2
3
4
y [mm]
0
10
20
30
40
50
60
70

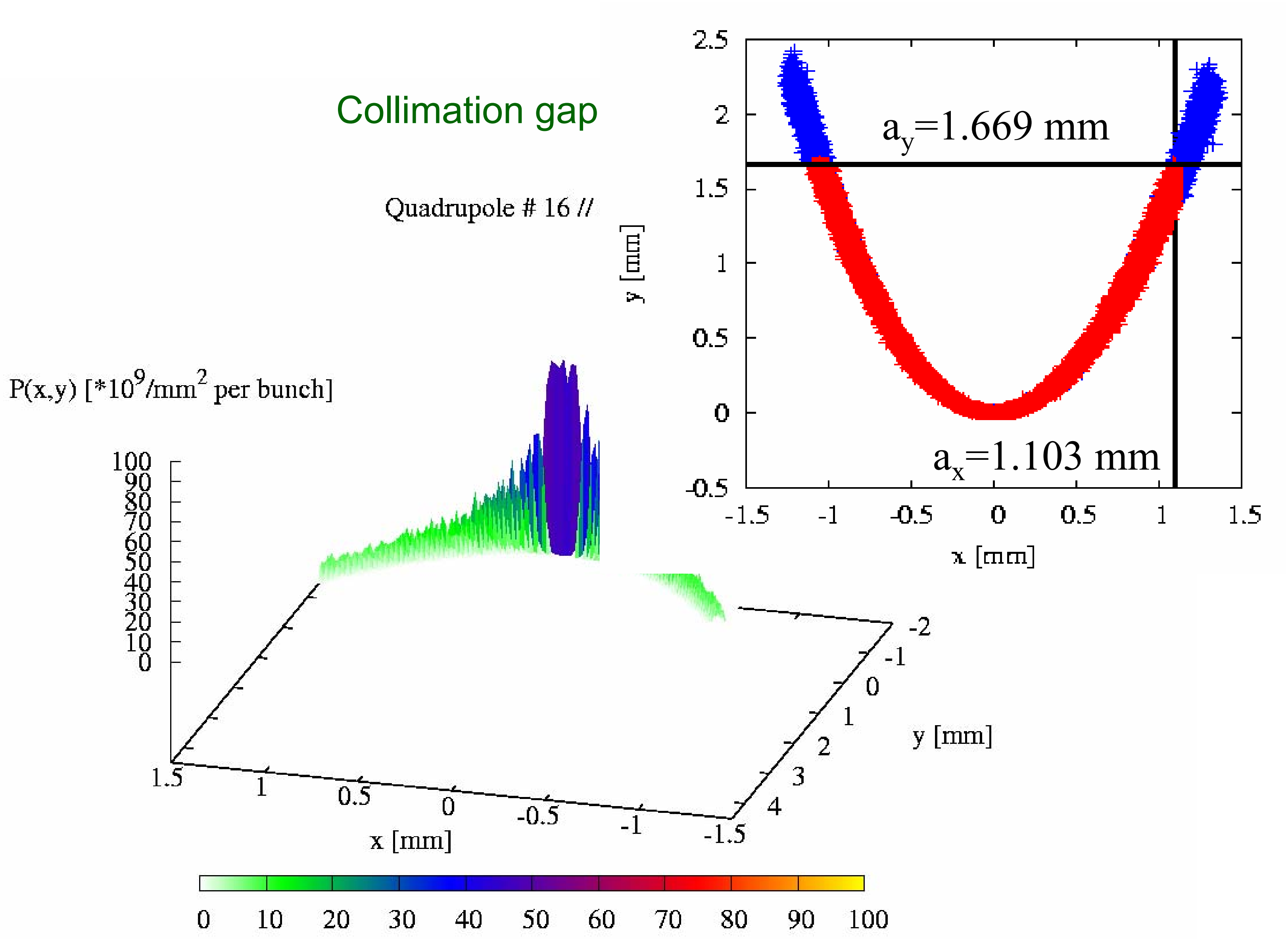

Quadrupole # 14
P(x,y) [*10^9/mm^2 per bunch]
70
60
50
40
30
20
10
0
1.5
1
0.5
0
-0.5
-1
-1.5
x [mm]
-2
-1
0
1
2
3
4
y [mm]
0
10
20
30
40
50
60
70

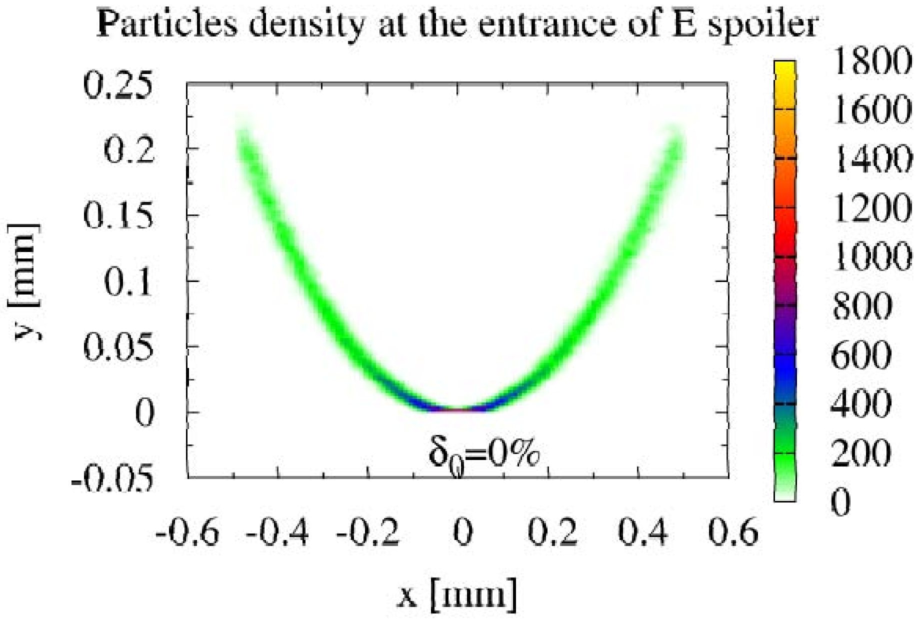

Quadrupole # 15
P(x,y) [*10^9/mm^2 per bunch]
80
70
60
50
40
30
20
10
0
1.5
1
0.5
0
-0.5
-1
-1.5
x [mm]
-2
-1
0
1
2
3
4
y [mm]
0
10
20
30
40
50
60
70
80

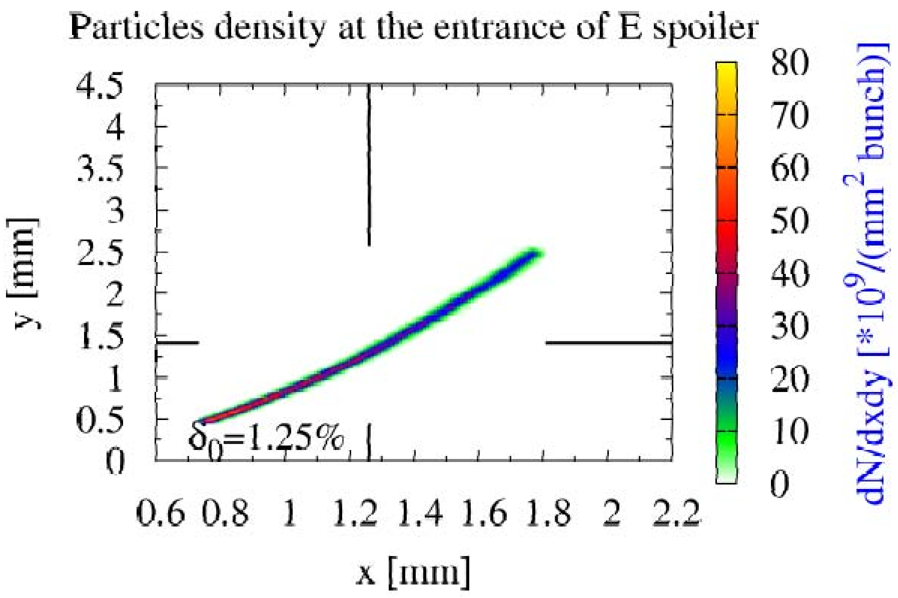


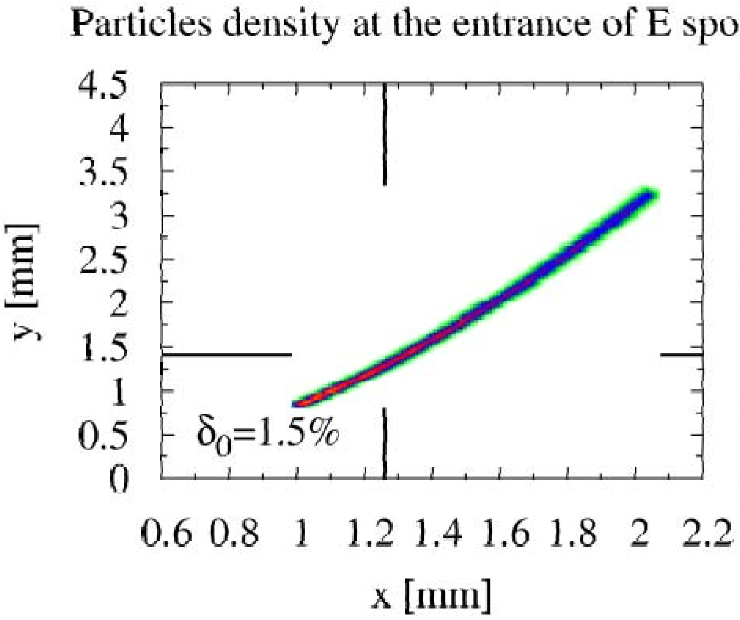
Quadrupole # 16 // Spoiler

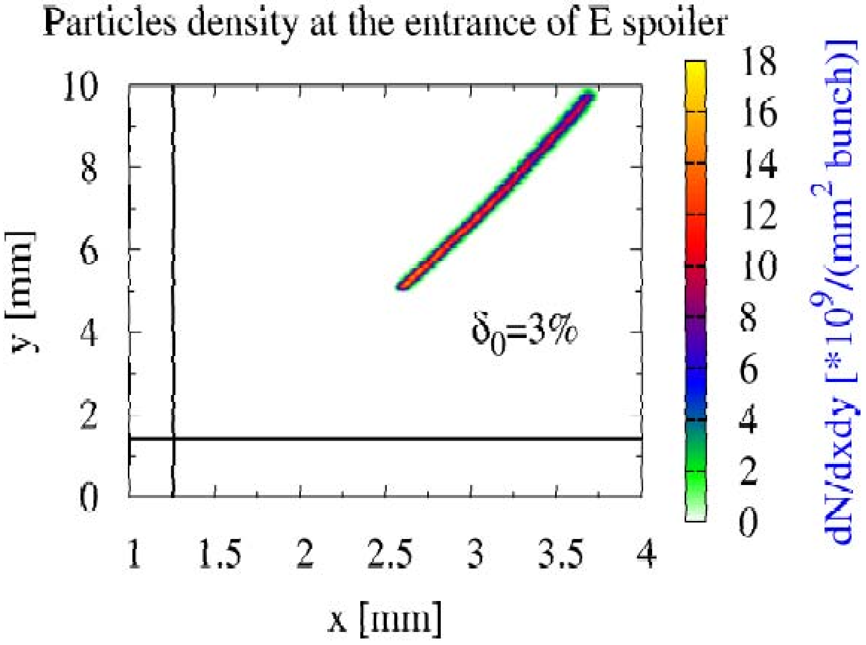
Collimation gap




Particles density at the entrance of E spoiler

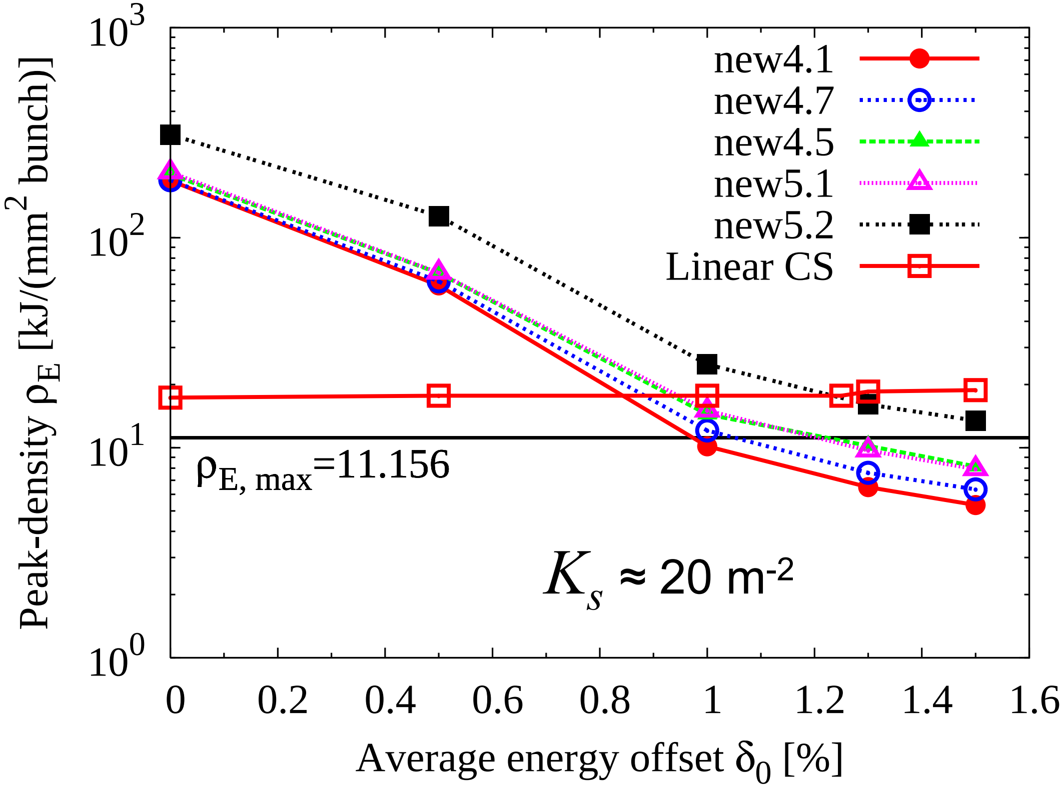

Particles density at the entrance of E spoiler


Particles density at the entrance of E spoiler


Particles density at the entrance of E spoiler

Peak density at the spoiler:

Beam is highly non-gaussian at the spoiler, and then it is the peak density of transverse enrgy which matters for the spoiler survival, not the rms beam size.



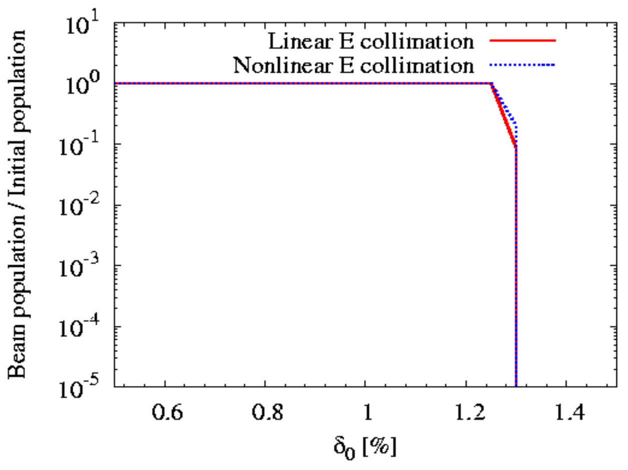
Spoiler survival is guarantee for off-momentum beams (>1%) using an integrated skew sextupole strength $K_s \approx 20$ m^{-2}

Collimation efficiency and machine protection

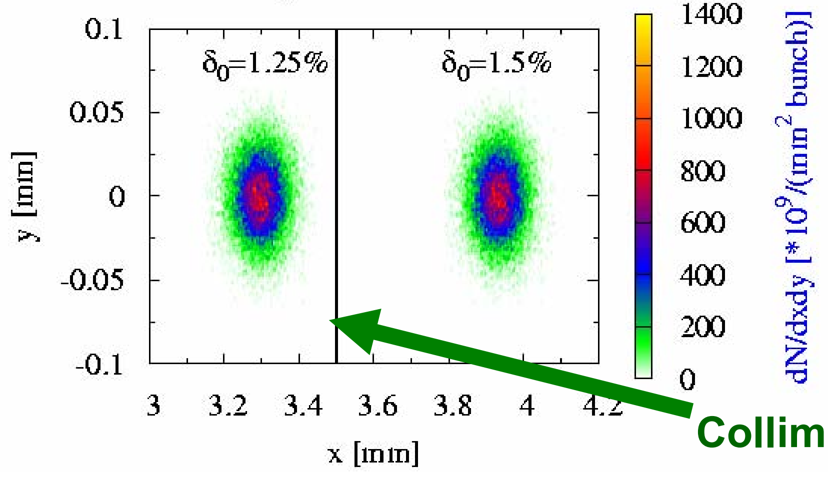
For failures scenarios mis-steered or errant beams will hit the energy spoiler

Tracking of gaussian beams of 10^5 macroparticles for different energy offsets and without energy spread. Beams with energy offset ≥ 1.3 % (energy collimation depth) are totally intercepted by the spoiler.

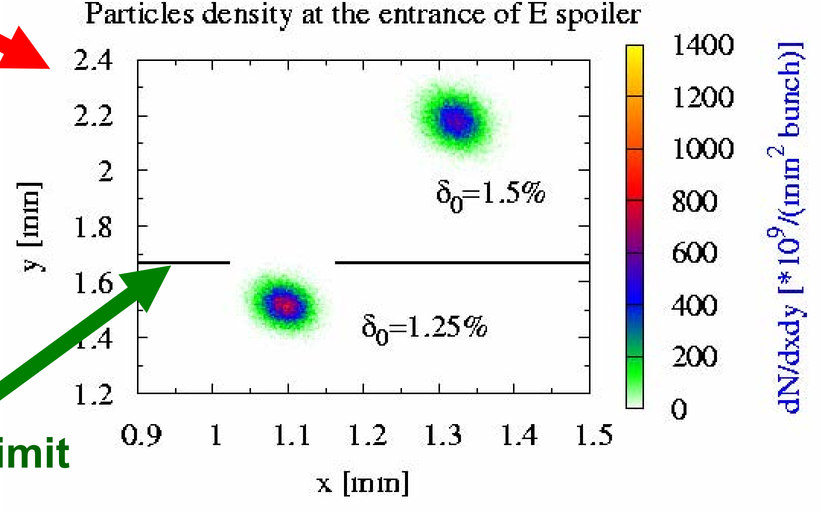
The nonlinear collimation system uses a vertical spoiler. Unlike the linear collimation system, the beam density is reduced by the nonlinear system as the beam energy offset increases. This helps to spoiler survival



Linear

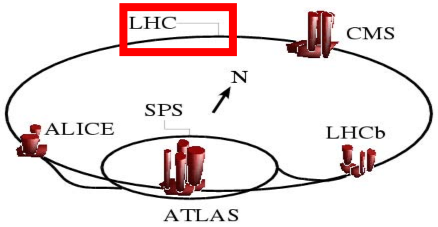


Nonlinear



Collimation limit

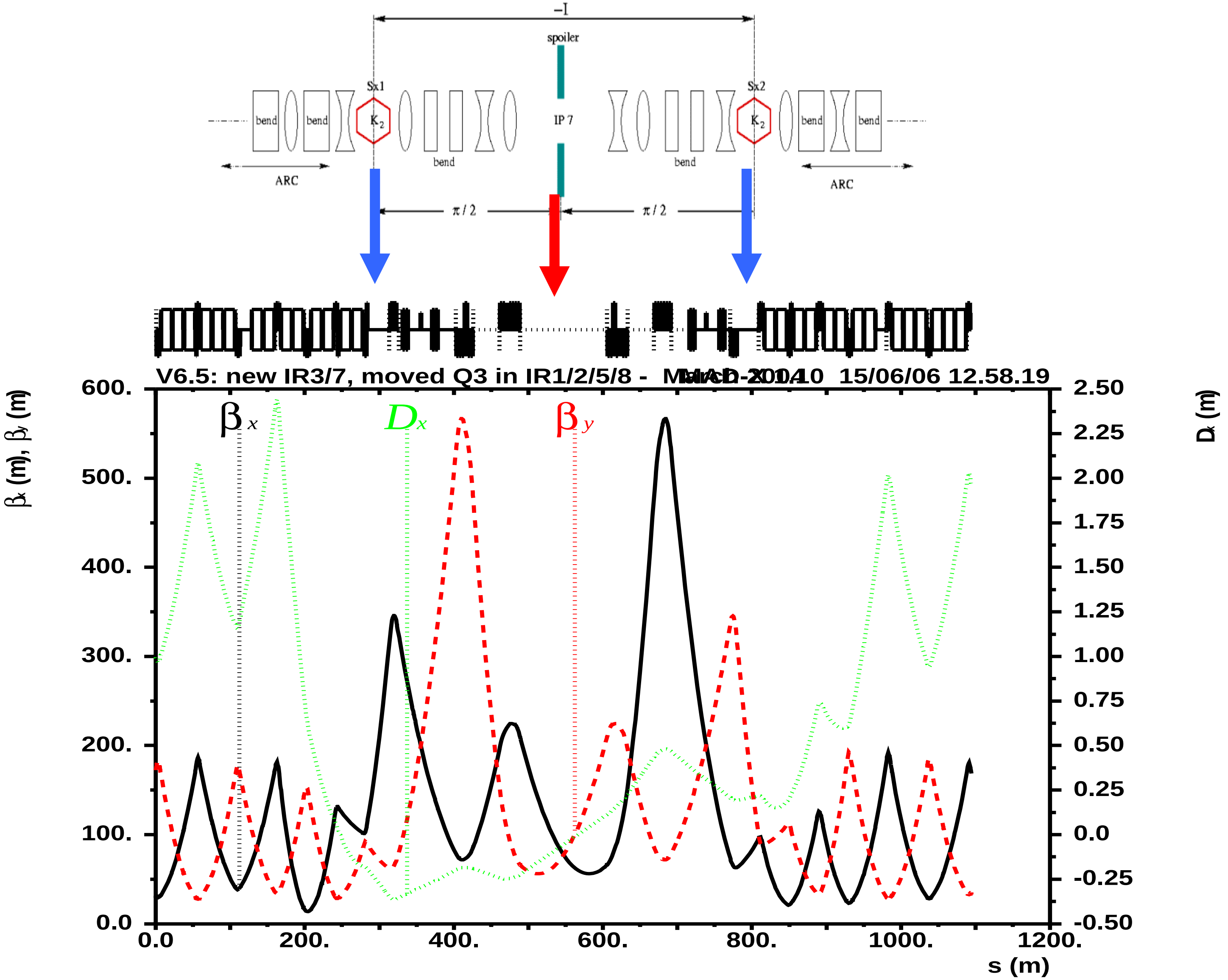
Nonlinear betatron collimation for



The changes respect to the CLIC optics designs:

- The LHC momentum spread is 2 orders of magnitude smaller than in CLIC, cannot be exploited for widening the beam during collimation
- Emittance growth from SR is insignificant, not constrain in the design of the collimation system
- The geometric vertical emittance is about 3 orders of magnitude larger than in CLIC

The optics solution:



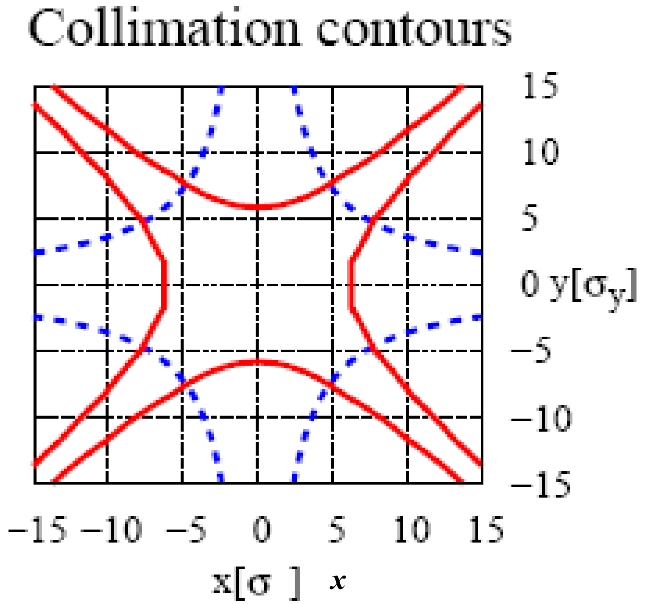
Performance from analytical studies:

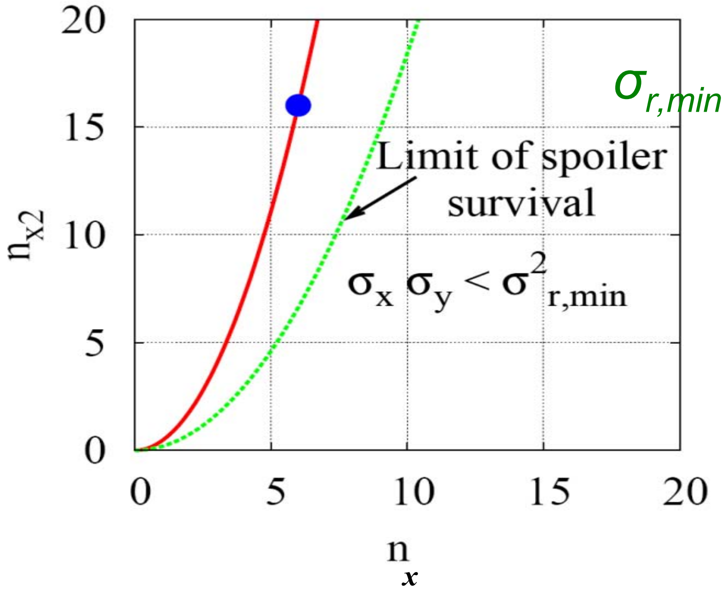
E	7.0	Tev
σ_ε	1.1×10^{-4}	
$\varepsilon_{x,y}$	503	pm
n_x	6	
n_y	6	
R_{12}^{sksp}	124.4	m
R_{34}^{sksp}	124.4	m
$\Delta\mu_{x,y}^{sksp}$	0.25	2π
K_s	7.0	m^{-2}
σ_x^{sp}	215.89	μm
σ_y^{sp}	263.96	μm
σ_r^{sp}	238.72	μm
a_y^{sp}	10.0	mm

$\sigma_{r,min} \approx 200\ \mu m$ ⬅

Collimation amplitudes and collimators apertures:

[J. Resta-López *et al,* EPAC'06 MOPCH091]





$\sigma_{r,min} \approx 200\ \mu m$

Normalized collimation amplitudes $n_x = n_y = 6$

Nomalized vertical spoiler aperture $n_{y2} = 8$

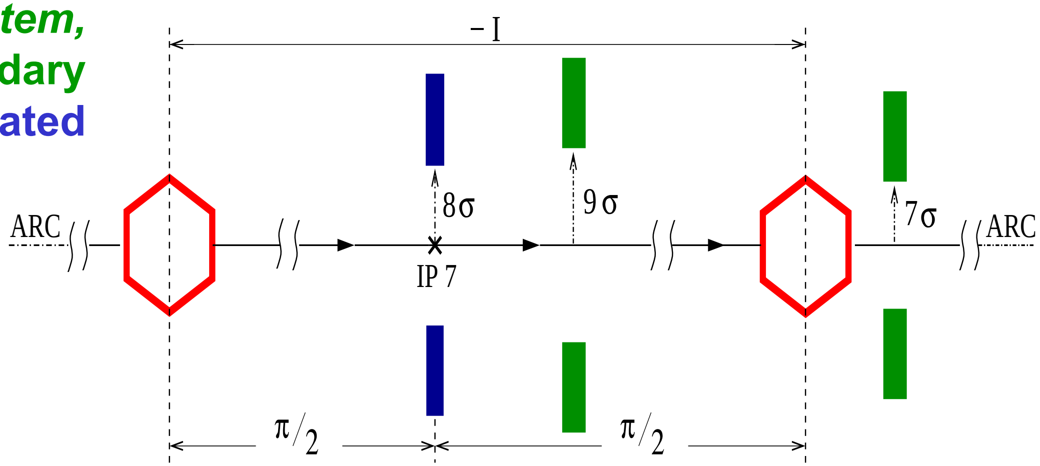
Normalized horizontal spoiler aperture $n_{x2} = 2n_{y2} = 16$

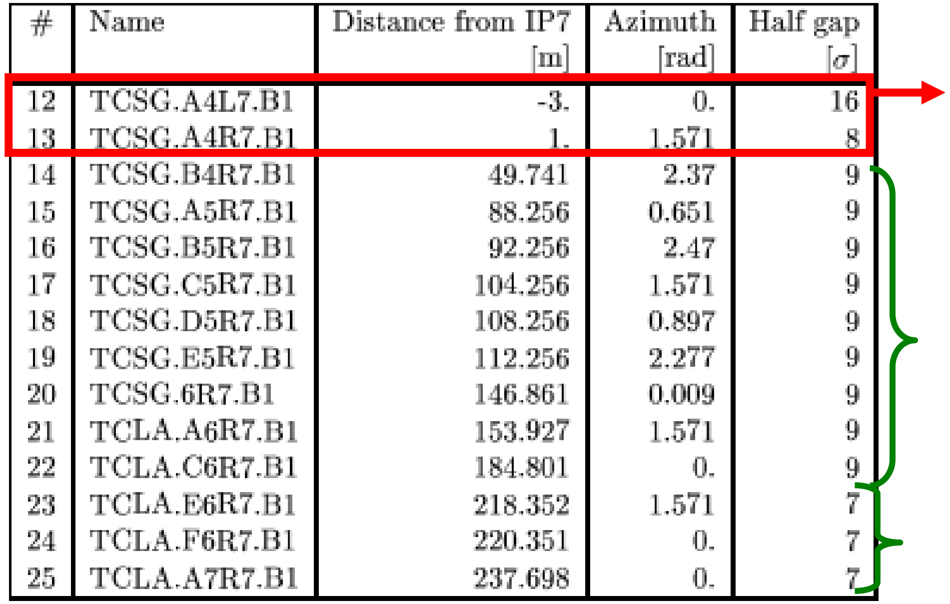
Primary and Secondary Collimators

Two-stage nonlinear collimation system, **considering primary and secondary collimators. Primary collimators are located close to IP7.**

[C. Bracco *et al*, EPAC'06 TUPLS018]

[G. Robert-Demolaize *et al*, EPAC'06 TUPLS019]





#	Name	Distance from IP7 [m]	Azimuth [rad]	Half gap [σ]
12	TCSG.A4L7.B1	-3.	0.	16
13	TCSG.A4R7.B1	1.	1.571	8
14	TCSG.B4R7.B1	49.741	2.37	9
15	TCSG.A5R7.B1	88.256	0.651	9
16	TCSG.B5R7.B1	92.256	2.47	9
17	TCSG.C5R7.B1	104.256	1.571	9
18	TCSG.D5R7.B1	108.256	0.897	9
19	TCSG.E5R7.B1	112.256	2.277	9
20	TCSG.6R7.B1	146.861	0.009	9
21	TCLA.A6R7.B1	153.927	1.571	9
22	TCLA.C6R7.B1	184.801	0.	9
23	TCLA.E6R7.B1	218.352	1.571	7
24	TCLA.F6R7.B1	220.351	0.	7
25	TCLA.A7R7.B1	237.698	0.	7

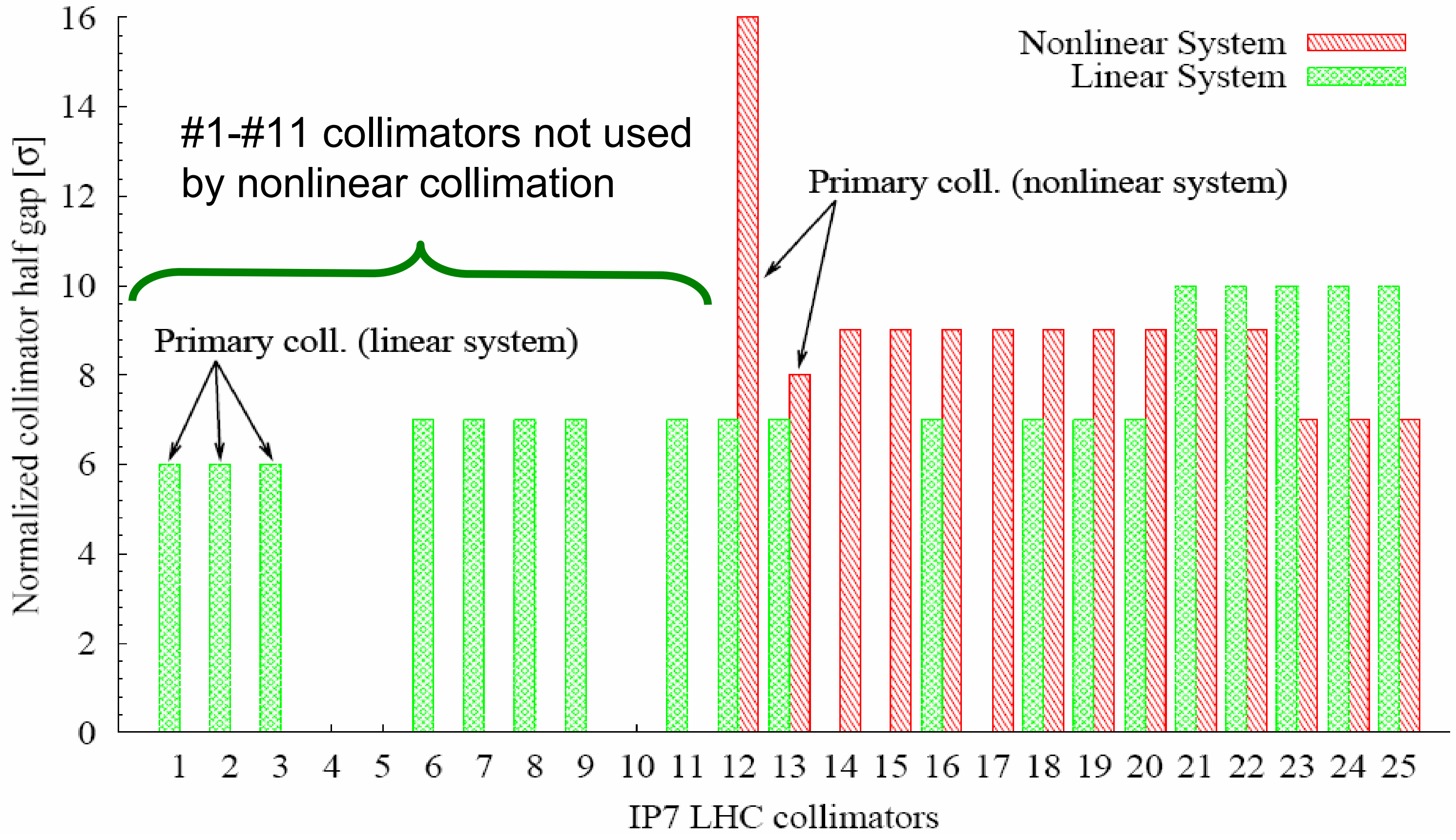
In the nonlinear collimation system these rectangular jaws play the role of primary collimators with apertures 16σ_x and 8σ_y

Secondary collimators with apertures of 9σ between the primary collimators and the second skew sextupole

Secondary collimators with apertures of 7σ downstream the primary collimators and the second skew sextupole

Comparison of Collimators Half Gap

A nonlinear collimation system allows larger mechanical apertures of the jaws. This is desired to avoid unacceptable high transverse resistive impedances of the collimators

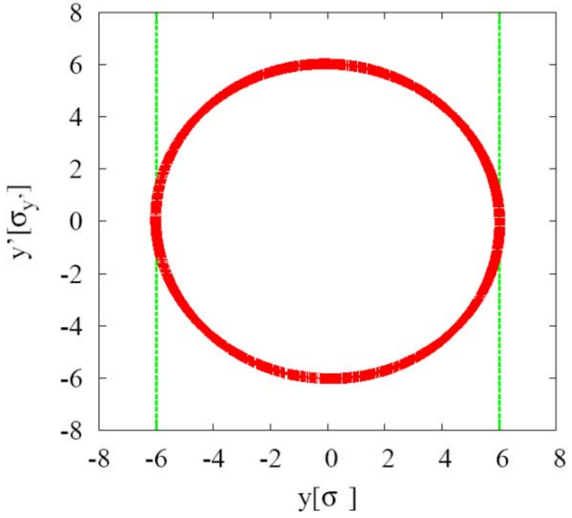


Studies on Collimation Efficiency

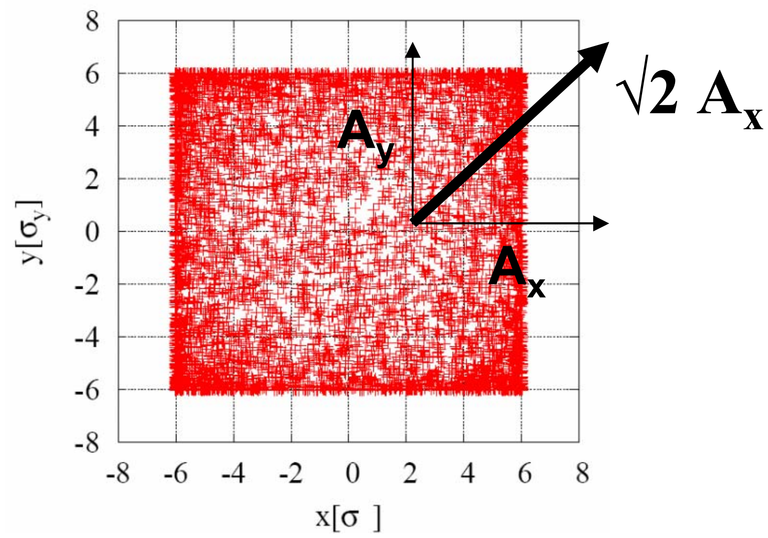
The cleaning efficiency has been studied by mean of multiparticle tracking using the code **CollTrack** [R. Assmann *et al.*] , a program which combines the collimator scattering routine **K2** [J.B. Jeanneret *et al.*] with the tracking program **SixTrack** [F. Schmidt *et al.*]

Beam halos from tracking of 5x10^6 protons for 200 turns:

Sample of vertical input halo



Sample of square input halo

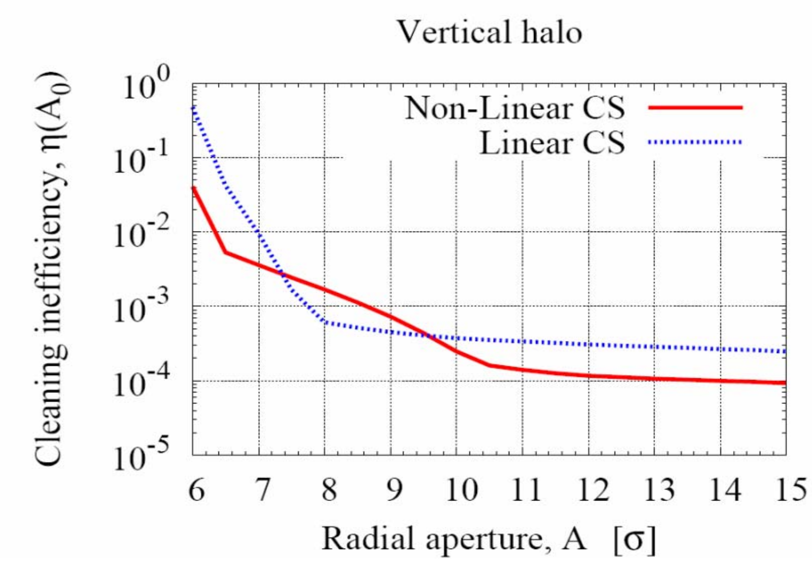


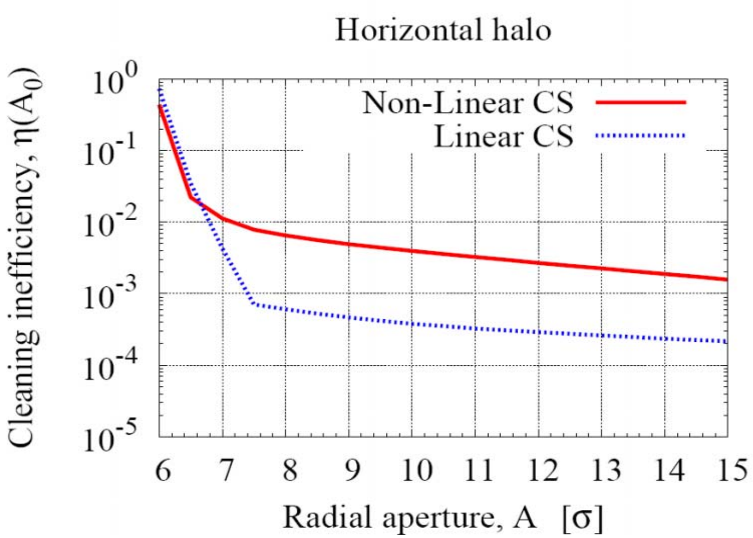
Studies on Cleaning Efficiency

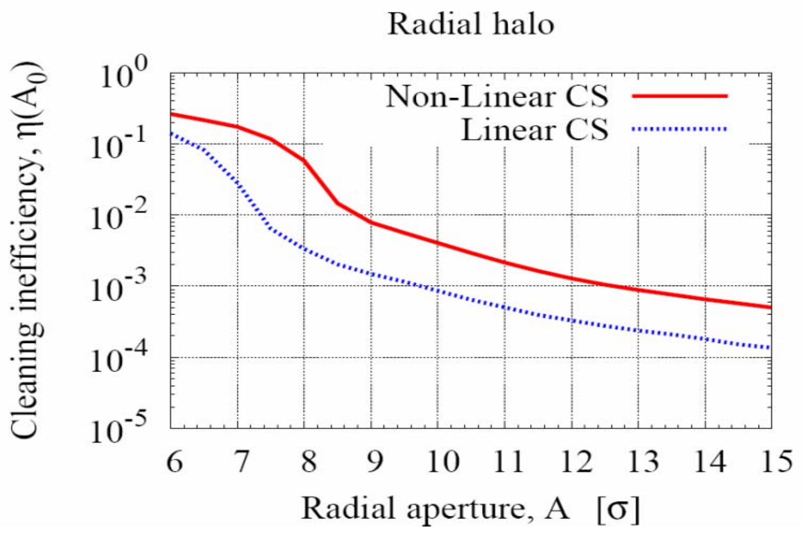
$$\eta_c(A_0) = \frac{N_p(A > A_0)}{N_{abs}}$$

number of protons with amplitude above A_0

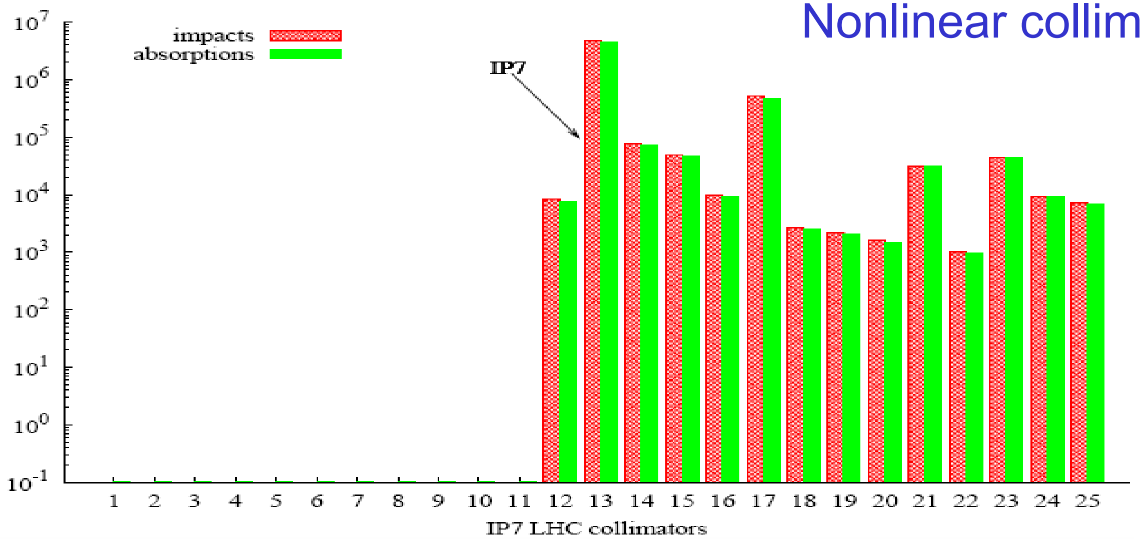
number of protons absorbed in cleaning insertion



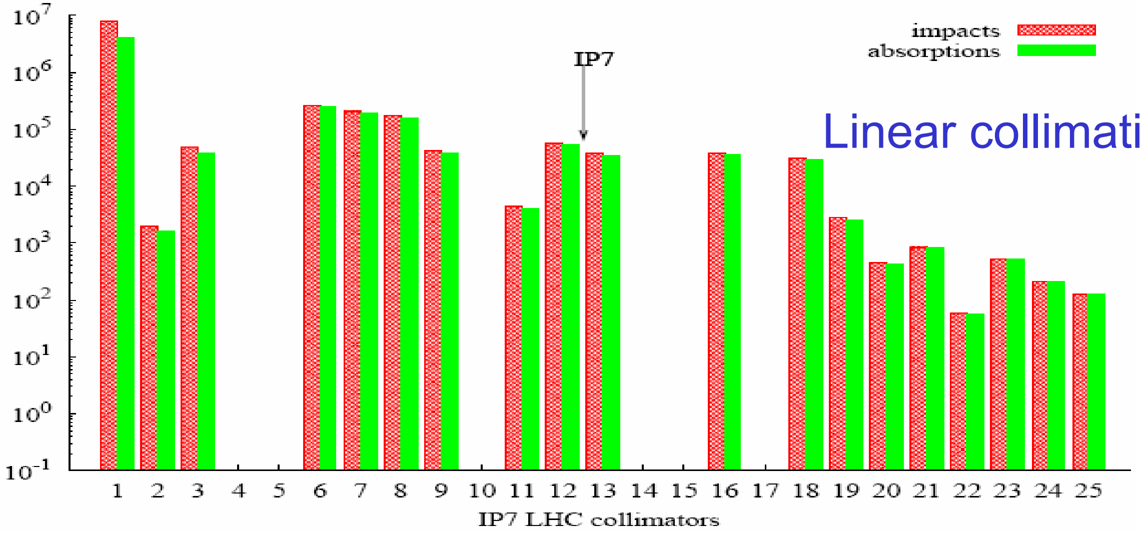




Impacts and Absorptions of a vertical halo:



Nonlinear collimation system



Linear collimation system

Outlook and Summary

- A nonlinear collimation system using two skew sextupoles and a single spoiler for the case of LC and CC appears to be competitive with the corresponding linear systems
- Compared with linear system, the transverse energy density is reduced at the spoilers, or primary collimators, thus increasing the probability of spoiler survival in case of miskicked beam impact.
- For CC the non linear collimation system allows larger aperture for the mechanical jaws, thereby, reducing the collimator impedance.

Thanks for contribution to:

J. Resta López

F. Zimmermann

D. Schulte

R. Tomás

R. Assmann

S. Redaelli

G. Robert-Demolaize

The system equations for LC:

We assume $\beta\varepsilon << D_x\delta$ both at the spoiler and the sextupoles. Furthermore beams are flats $x_\beta >> y_\beta$

$$\left\langle x_{sp}^2 \right\rangle \approx D_{x,sp}^2 \left\langle \delta^2 \right\rangle + R_{12}^2 K_s^2 D_{x,sext}^2 \left\langle \delta^2 \right\rangle \left\langle y_{\beta,sext}^2 \right\rangle$$

$$\left\langle x_{sp} \right\rangle \approx D_{x,sp} \left\langle \delta \right\rangle$$

$$\left\langle y_{sp}^2 \right\rangle \approx \frac{1}{4} R_{34}^2 K_s^2 D_{x,sext}^4 \left\langle \delta^4 \right\rangle$$

$$\left\langle y_{sp} \right\rangle \approx \frac{1}{2} R_{34} K_s D_{x,sp}^2 \left\langle \delta^2 \right\rangle$$

horizontal and vertical mean squared position and average beam offset at the spoiler

The system equations for CC:

We assume $\beta\varepsilon >> D_x\delta$ both at the spoiler and the sextupoles.

$$\left\langle x_{sp}^2 \right\rangle \approx \left\langle x_{\beta,sp}^2 \right\rangle + R_{12}^2 K_s^2 \left\langle x_{\beta,sext}^2 \right\rangle \left\langle y_{\beta,sext}^2 \right\rangle$$

$$\left\langle x_{sp} \right\rangle \approx 0$$

horizontal and vertical mean squared position and average beam offset at the spoiler

$$\left\langle y_{sp}^2 \right\rangle \approx \left\langle y_{\beta,sp}^2 \right\rangle + \frac{1}{4} R_{34}^2 K_s^2 \left(\left\langle x_{\beta,sext}^4 \right\rangle + \left\langle y_{\beta,sext}^4 \right\rangle - 2 \left\langle x_{\beta,sext}^2 \right\rangle \left\langle y_{\beta,sext}^2 \right\rangle \right)$$

$$\left\langle y_{sp} \right\rangle \approx -\frac{1}{2} R_{34} K_s \left(\left\langle y_{\beta,sext}^2 \right\rangle - \left\langle x_{\beta,sext}^2 \right\rangle \right)$$

The system equations for LC:

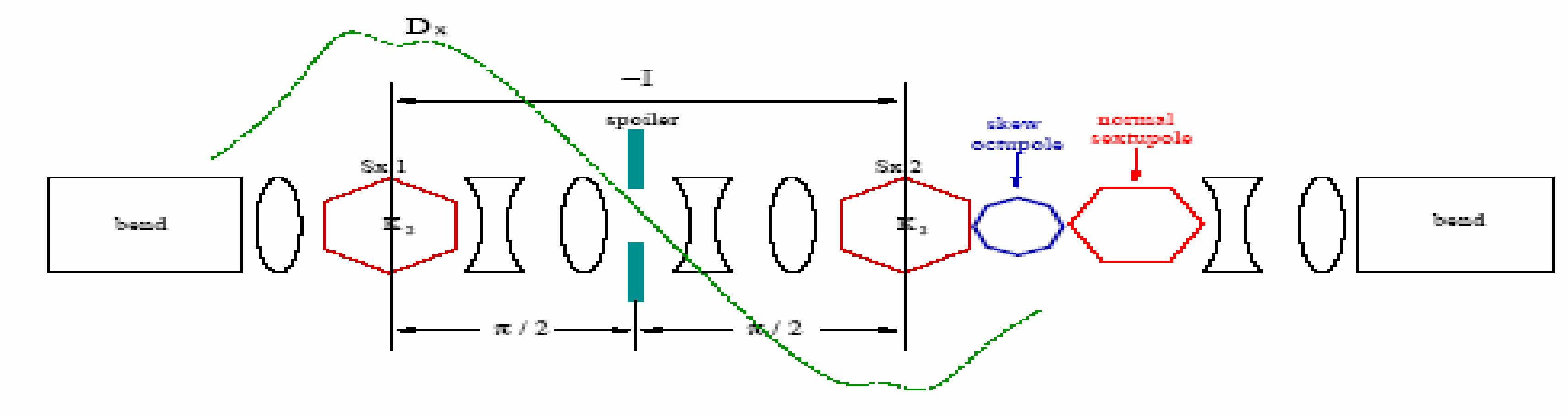
By combining these equations we could collimate in both betatron phases and in energy using a single spoiler.

⬇

If we opt for nonlinear betatron collimation, the other phase could also be collimated by installing a “pre” skew sextupole with a phase advance of $\pi/2$ in front of the first skew sextupole in a non dipersive location.

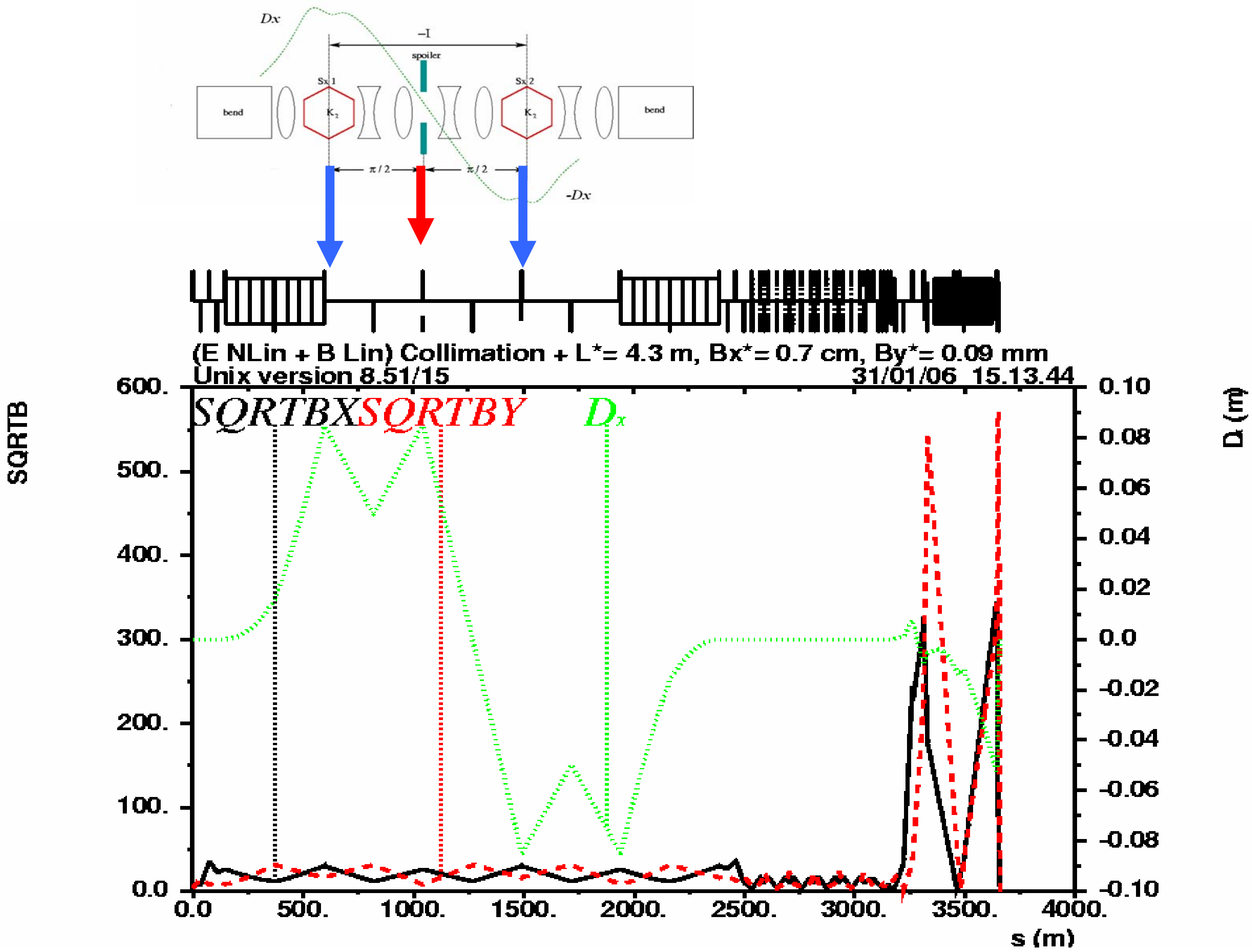
Luminosity optimization:

Optimization of the beam sizes with a MAPCLASS (Python code) by adding two additional multipoles (skew octupole and normal sextupole) for local cancellation of the higher order aberrations

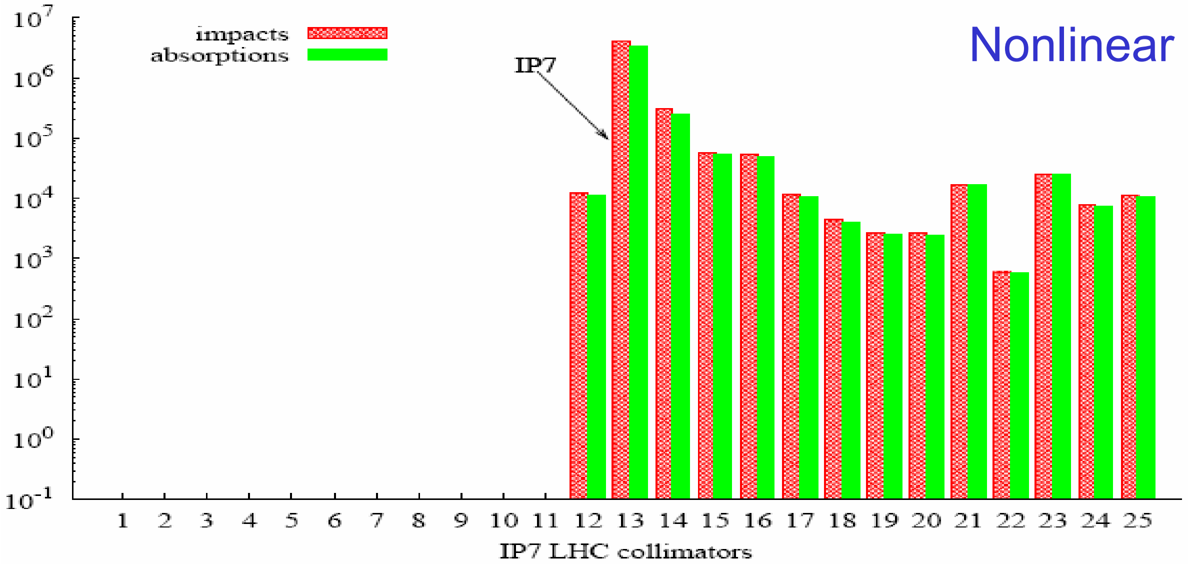


[R. Tomás *et al*, EPAC'06 MOPLS100]

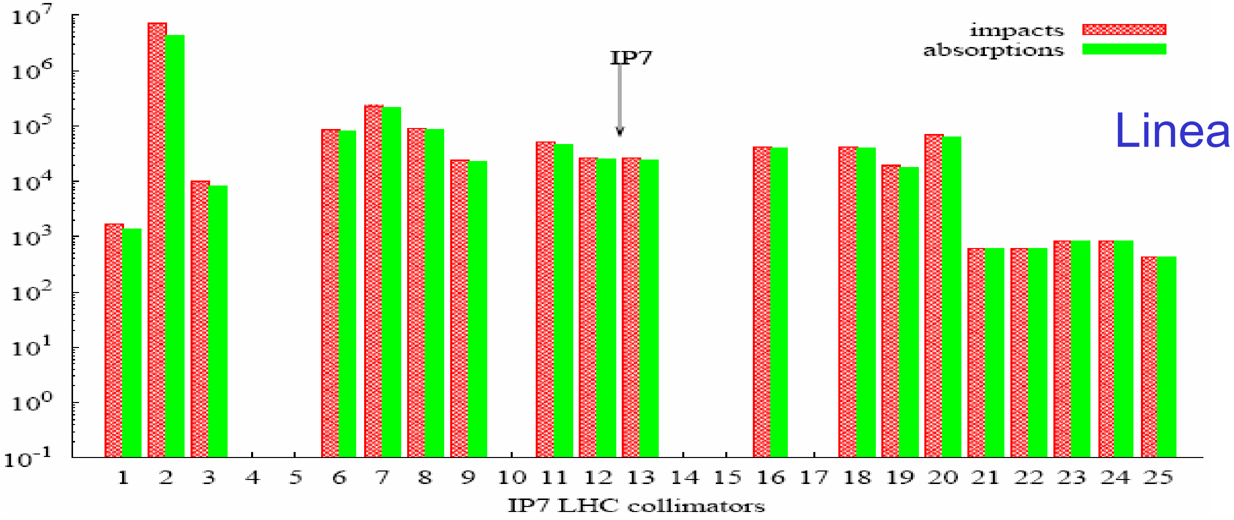
The optics solution in the BDS:



Impacts and Absorptions of a horizontal halo:

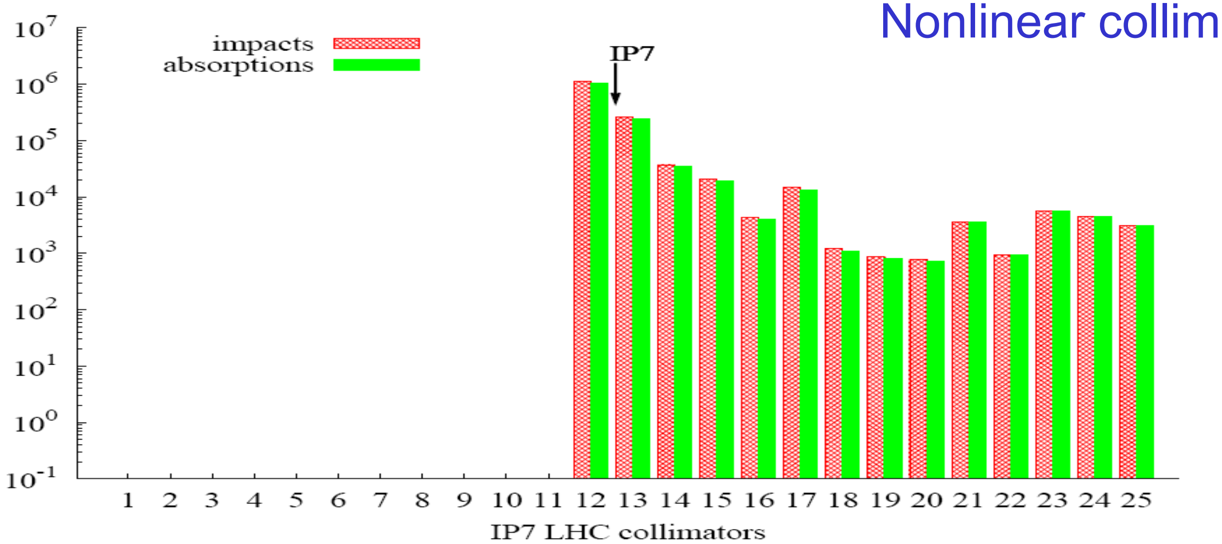


Nonlinear collimation system

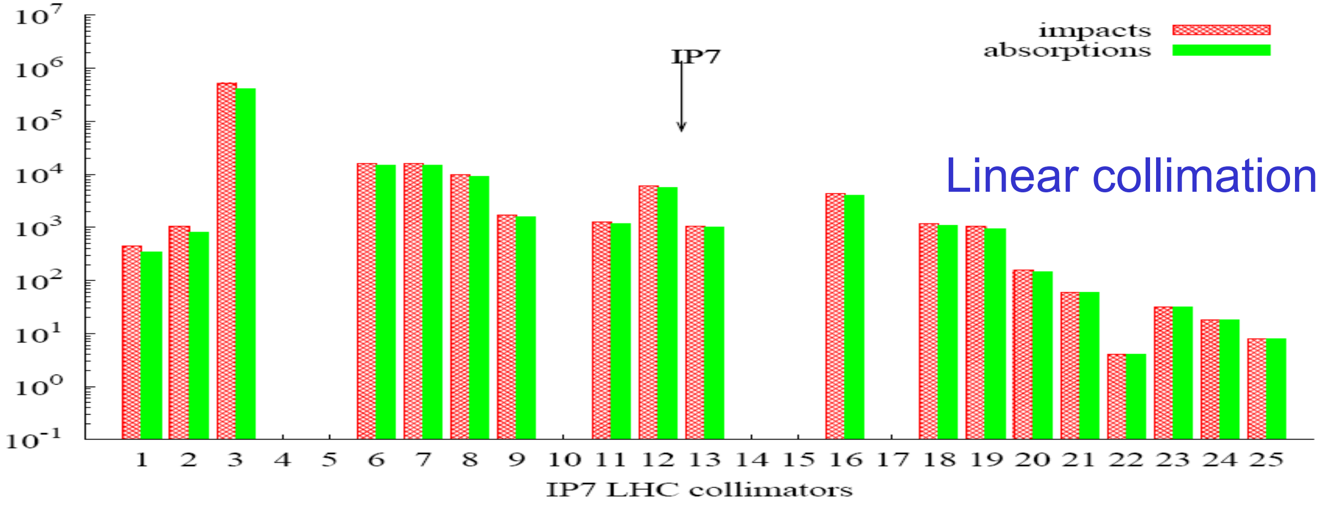


Linear collimation system

Impacts and Absorptions of a radial halo:



Nonlinear collimation system



Linear collimation system