3^{rd} Meeting of the LHC Beam Cleaning Study Group 24.10.2001

Present: *R. Assmann (chairman), I. Baishev, H. Burkhardt, G. Burtin, B. Dehning, C. Fischer, J.B. Jeanneret, R. Jung, V. Kain, D. Kaltchev, R. Schmidt*

1) Comments on previous minutes (all)

G. Burtin commented that he had another meeting on installation accuracy. It is estimated that collimators can be installed at both ends with 100 μm accuracy. The work on a model for an LHC collimator jaw has been started. C. Fischer asked about the heating of a collimator jaw. J.B. Jeanneret gave the heating to be 500 W for the secondary collimator, less for the primary.

2) Move of Q7 in Cleaning Insertion IR3 (D. Kaltchev)

D. Kaltchev presented the consequences of moving Q7 in IR3. This was requested for standardization of LHC components and the associated savings in cost. Dobrin showed a solution that did not alter significantly the cleaning efficiency.

3) Collimation Efficiency Versus Length (R. Assmann)

R. Assmann presented results on the cleaning efficiency of the betatron cleaning insertion versus the effective length of primary and secondary jaws. This is important, as the effective collimator length can be strongly reduced if the jaw is deformed (due to overheating etc). For shorter primary collimator length the cleaning efficiency is slightly reduced but the cleaning needs many more turns. For shorter secondary collimator length, the cleaning efficiency can be very strongly reduced. The presentation is appended in the PDF version of the minutes and is available on our web site.

4) Collimator Counting Rates (B. Dehning)

B. Dehning showed results on collimator counting rates, important for the beam loss monitor system. He summarized the definitions, the quench levels, and the longitudinal energy deposition in the shielding. The presentation is appended in the PDF version of the minutes and is available on our web site. B. Dehning raised the question whether it will be possible to differentiate between the upper and lower jaw. I. Baishev suggested to measure the charge directly in the jaw. R. Schmidt asked about the effect from orbit oscillations.

5) Next meeting

Next meeting will take place 10h30 November 7th, 2001. B. 112, 4C17.

Collimation efficiency versus active length

G. Burtin (drawings/list on web):

Parameter	LEP specified	LEP achieved	Limit
Flatness[1]	50 μm	120 μm	10-15 μm
Surface roughness[2]	0.8 μm	not measured (2 μm?)	-
Position set size[3]	uncritical	2.5 – 5.0 μm	-
Repeatability	uncritical	½ step ?	-

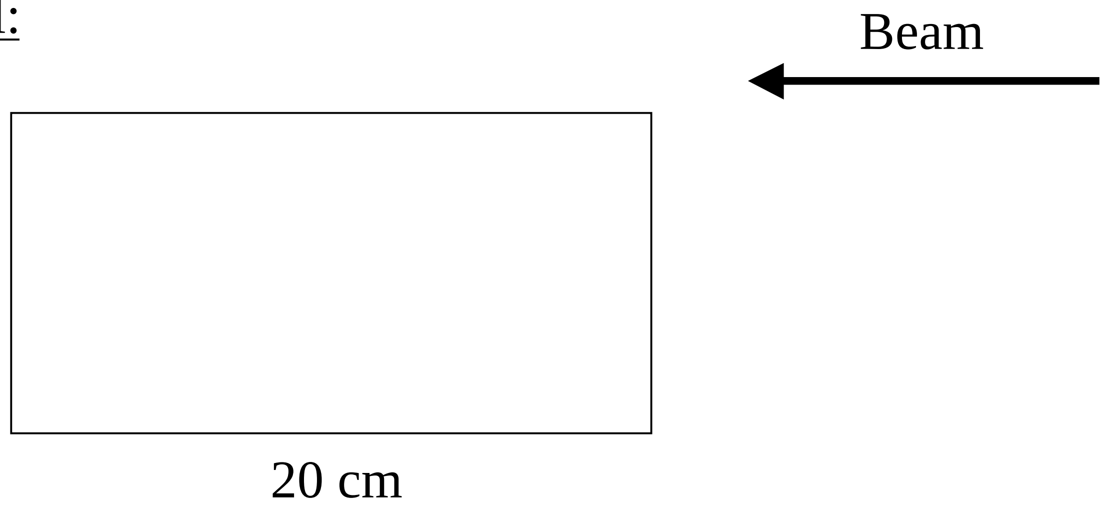
Compare to ~ μm impact parameter…

The collimators are referred with about **10 μm accuracy** (at an ambient temperature of 20 °C) to an external reference line, which ideally goes parallel to the beam axis. The reference line is used to set both the horizontal and vertical orientations of the collimator jaw. The **installation error is expected to be about 100 μm**. The accuracy of the reference system and of the installation will determine the angle between the jaw surface and the beam axis (longitudinal tilt). **A non-zero longitudinal tilt can add to the non-flatness of the jaw and can cause a further reduction of the active collimator length.** The collimators are also referred into an external x-y reference plane that is important in order to obtain the correct x-y angle of the collimator surface (transverse tilt).

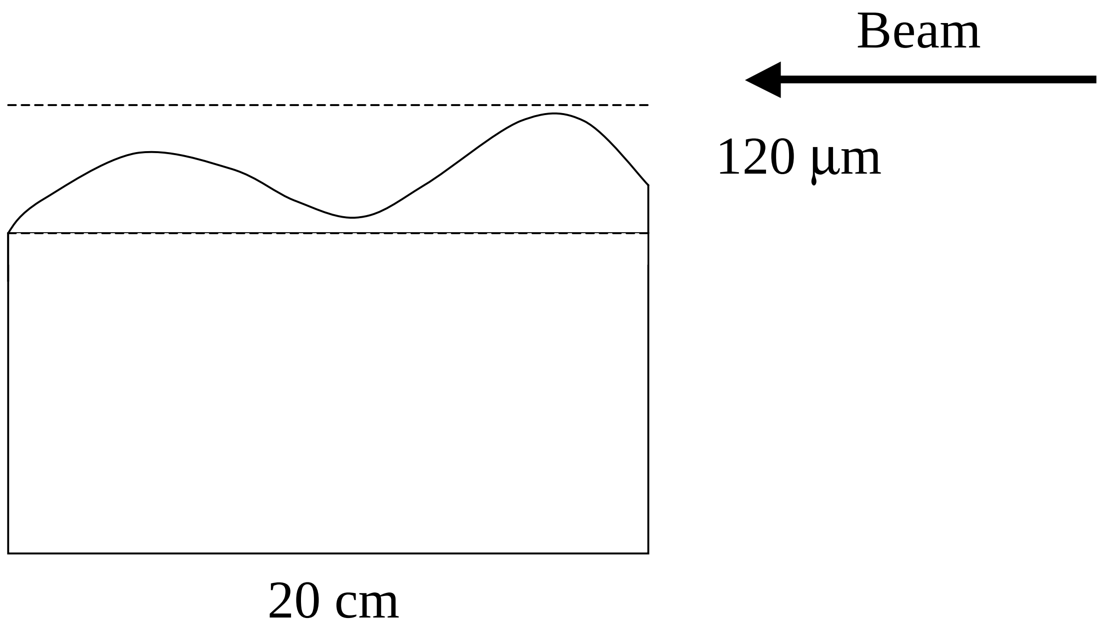
After installation, only the collimation depth can be adjusted (distance between jaw surface and beam). The longitudinal and transverse tilts cannot be adjusted and must be lived with.

My picture of collimator geometry:

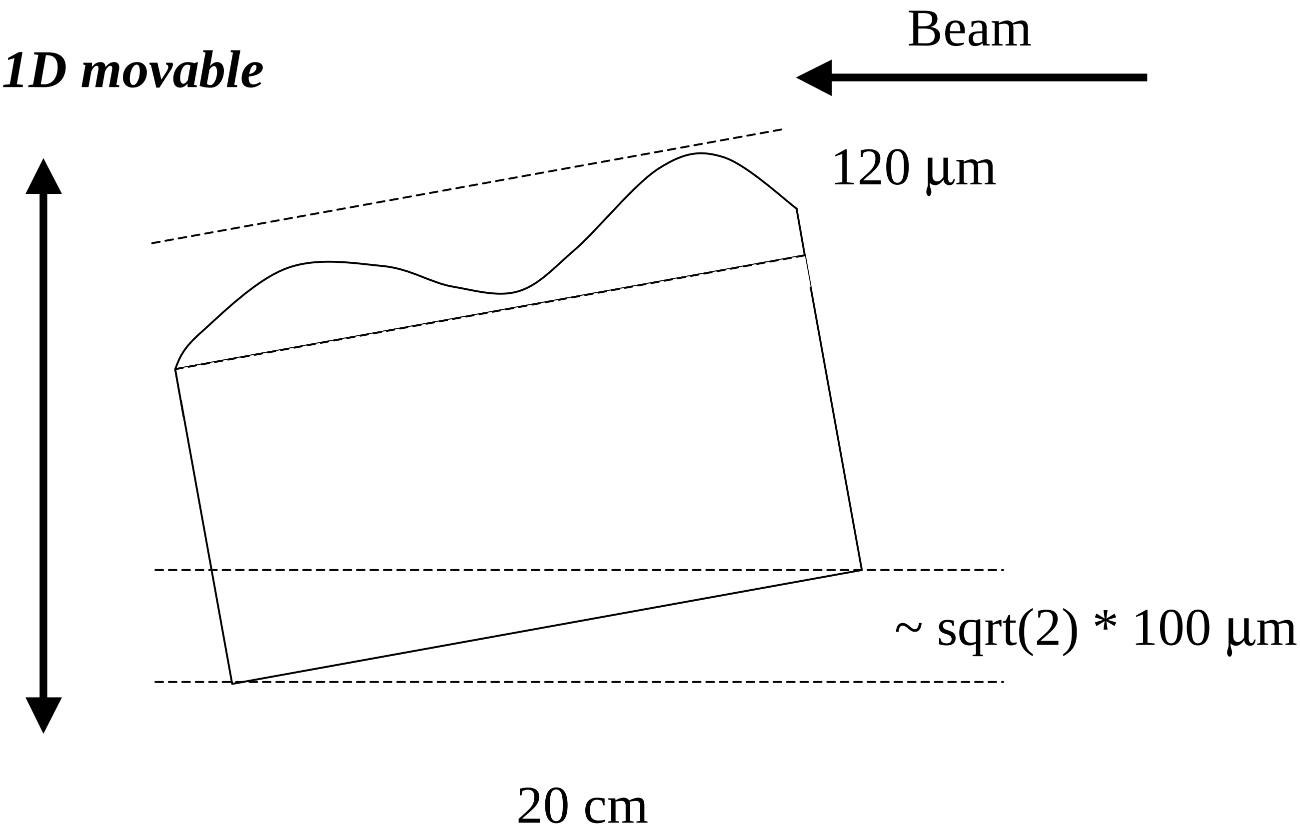
Ideal:



With surface non-flatness:



With surface non-flatness and installation error:



Plus average beam angle (a not equal zero)

~17 µrad for considered collimator…
(~17 µm for 1 m length)

Worst non-flatness with respect to beam direction:

~ 270 µm if we add contributions listed above

Compare to beam sigma of ~ 200 µm at 7 TeV…

Effect of collimator active length?

Consider:

7 TeV

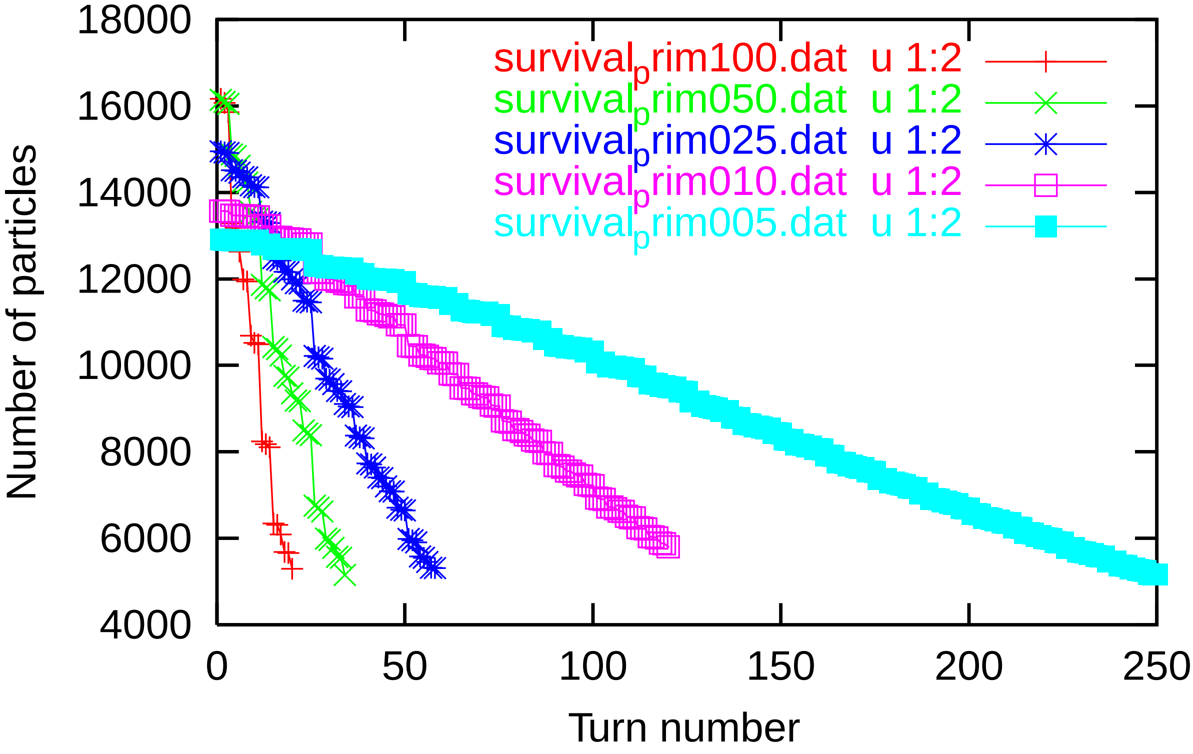
Perfect system

Collimation depth 6/7 sigma

Efficiency of primary vertical collimator

No detailed model of non-flatness yet

Change overall length of primary/secondary collimators


survival_prim100.dat u 1:2
survival_prim050.dat u 1:2
survival_prim025.dat u 1:2
survival_prim010.dat u 1:2
survival_prim005.dat u 1:2
Number of particles
18000
16000
14000
12000
10000
8000
6000
4000
0
50
100
150
200
250
Turn number

Look at survival of particles:

Note: Reduction of number of impacting particles!

Particles survive much longer!

Equilibrium between:

Lost particles	N_p per turn
Absorption efficiency	fraction R per turn

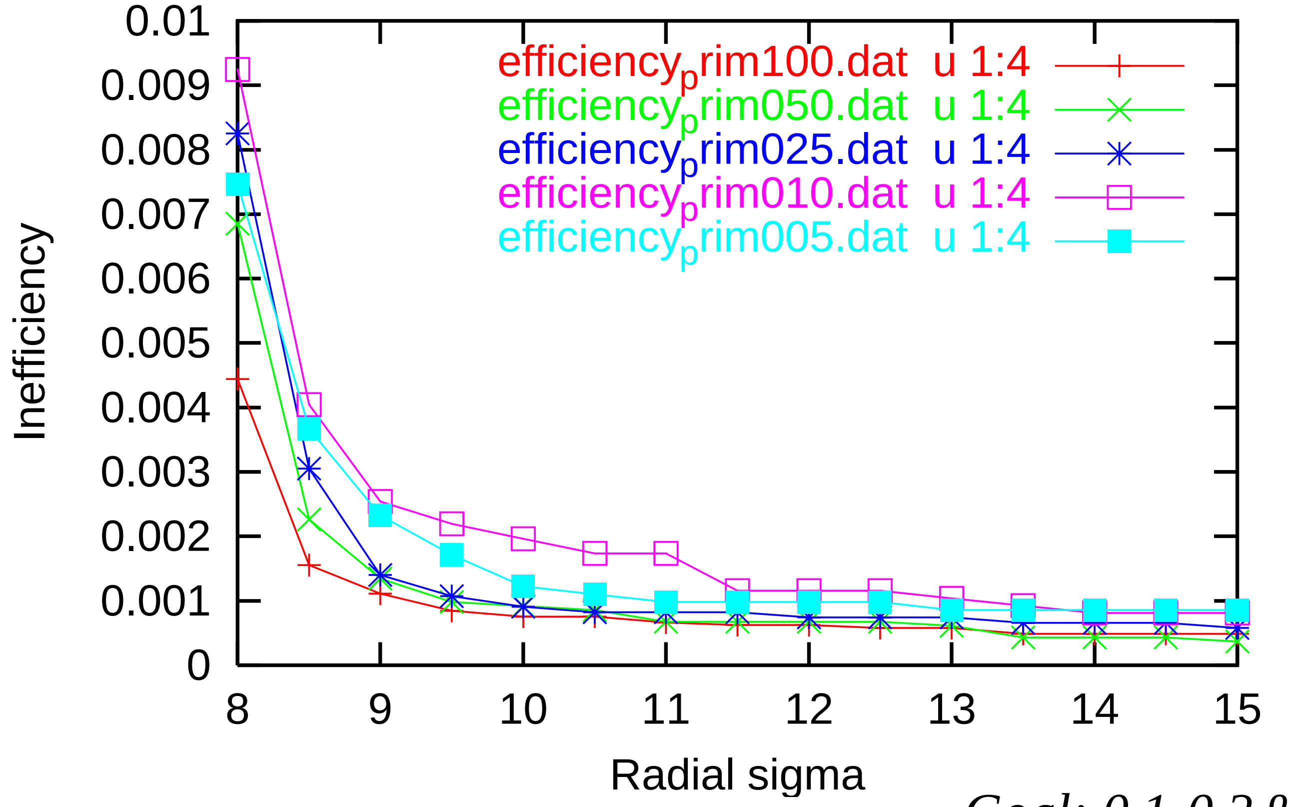
N_p = 10e4/turn	R=5%/turn	2 10e5 part at 6-7 sigma
N_p = 10e4/turn	R=0.1%/turn	1 10e7 part at 6-7 sigma

Another kind of efficiency is here…

Inefficiency at given radial amplitudes:

What fraction of particles escape the collimation system with the given amplitudes?

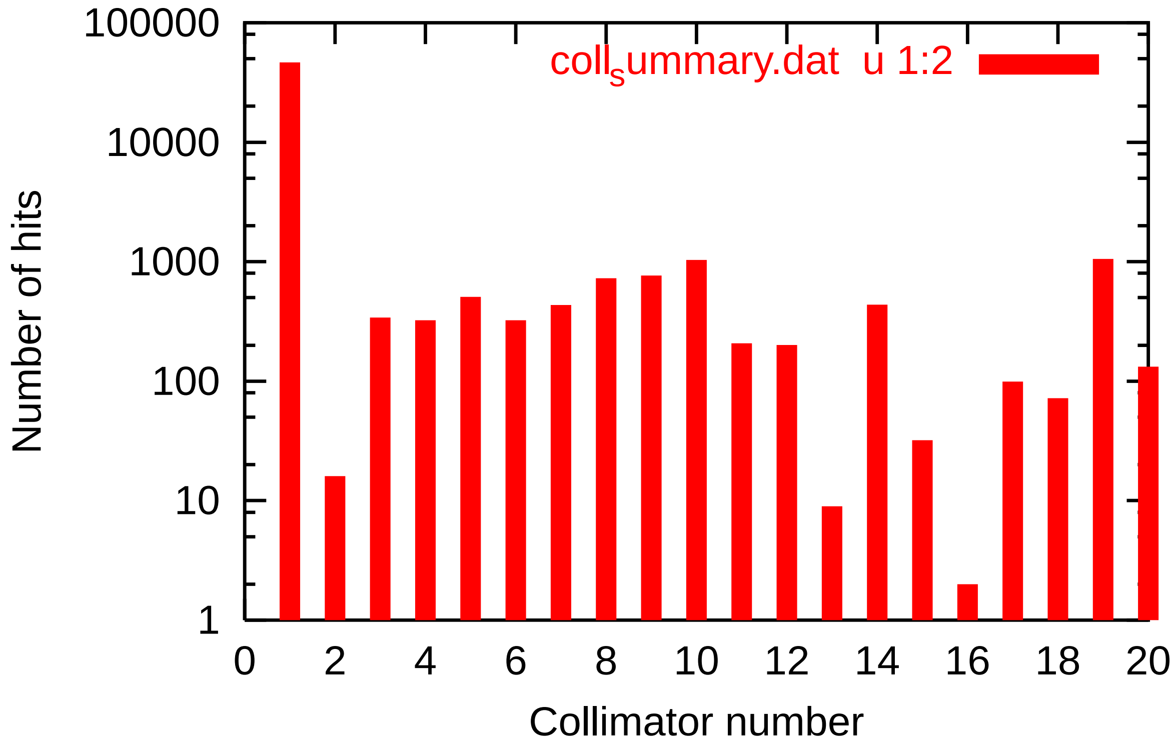
Number of part. at N rad sigma / Number of absorbed part.

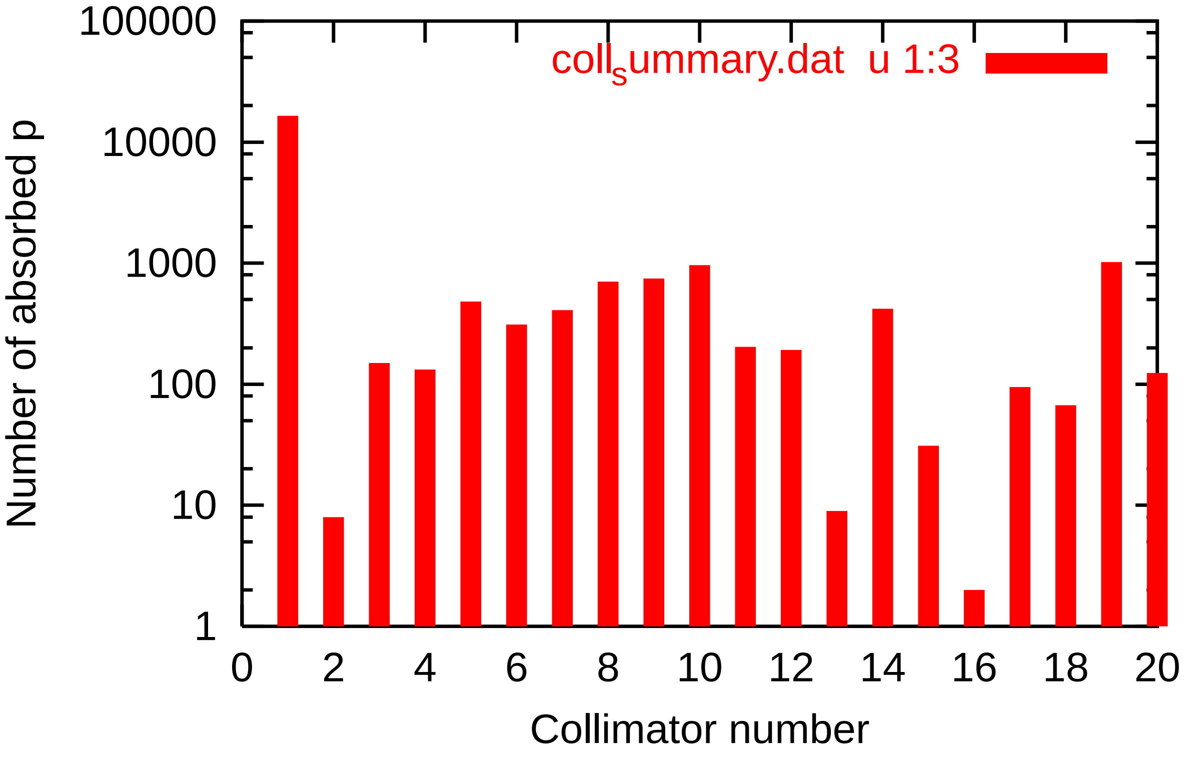


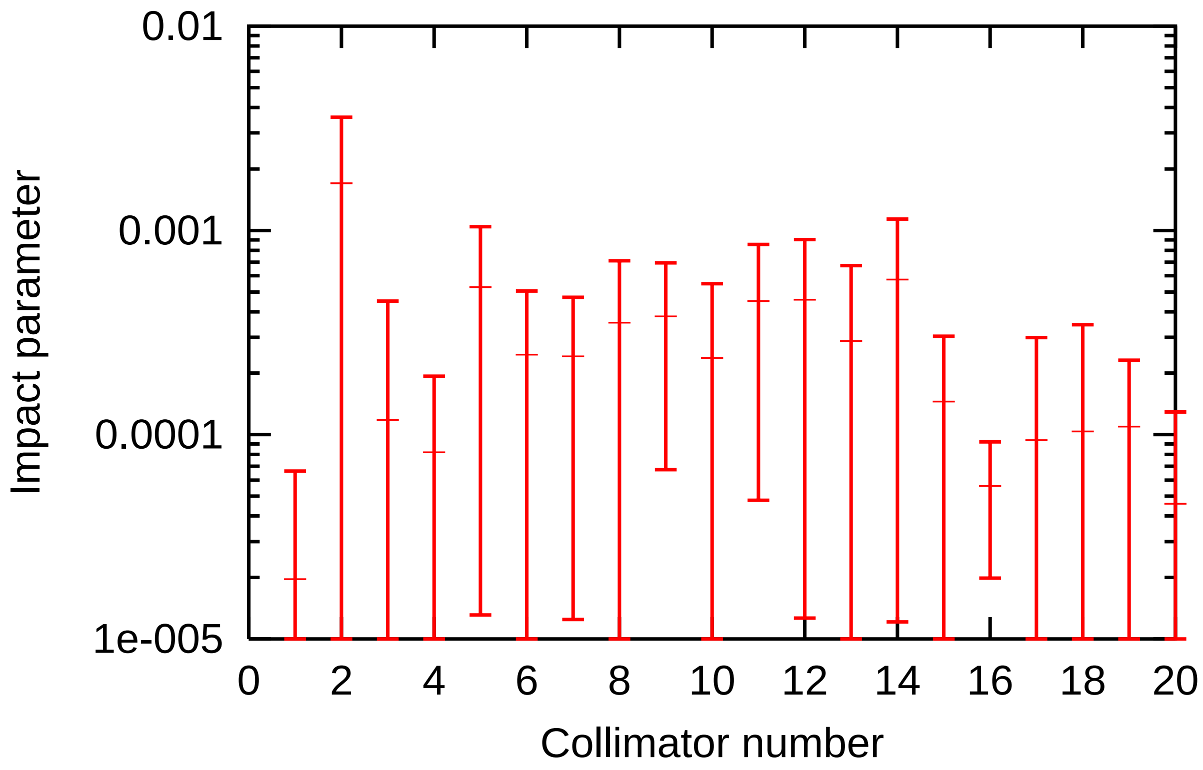
Goal: 0.1-0.2 %

Larger inefficiency for shorter primary jaws!

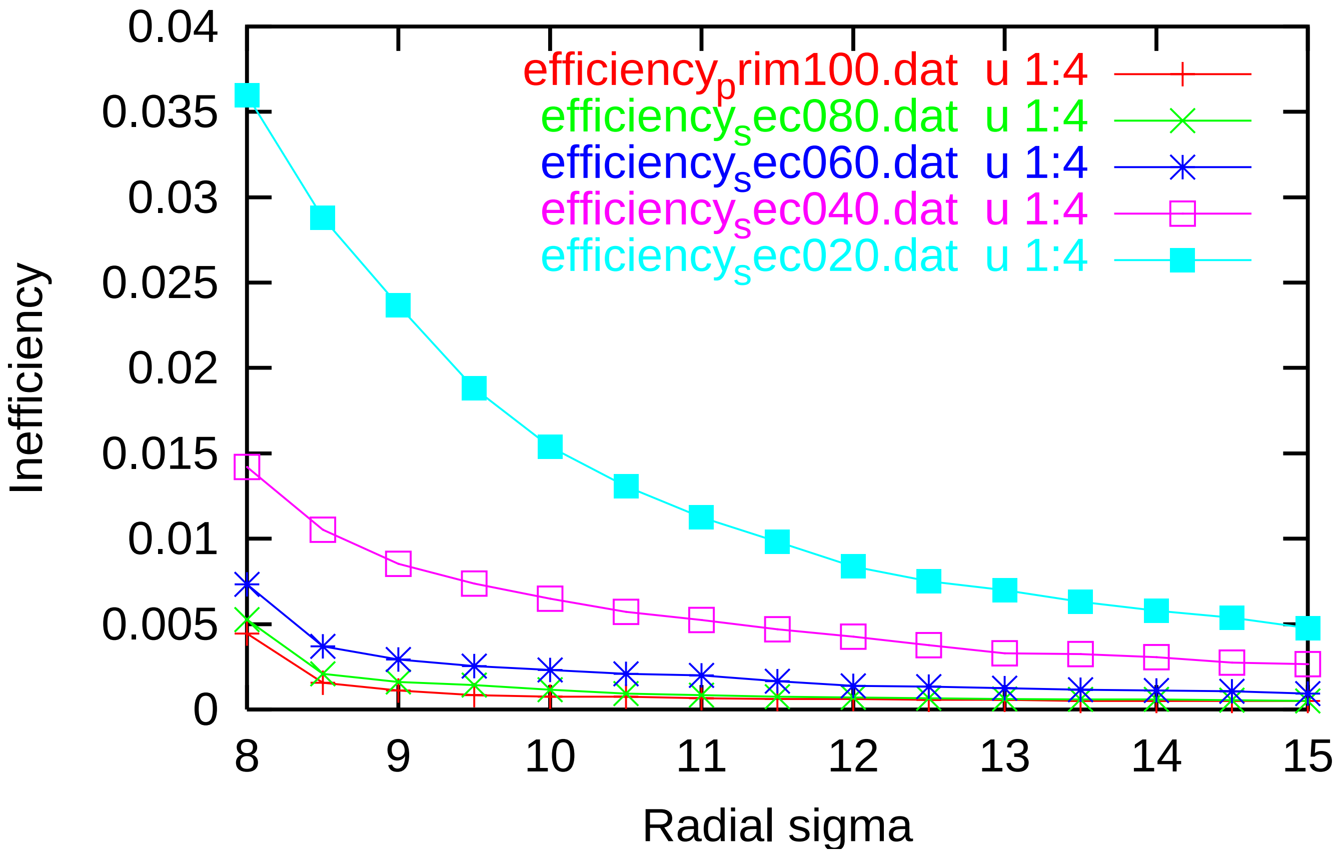
Why: Shorter primary jaws
Smaller scattering angles received
Smaller impact parameters at secondary coll.
Less active length for secondary jaws
More particles in tertiary halo


100000
10000
1000
100
10
1
0
2
4
6
8
10
12
14
16
18
20
Number of hits
Collimator number
coll$_s$ummary.dat u 1:2


100000
10000
1000
100
10
1
0
2
4
6
8
10
12
14
16
18
20
Number of absorbed p
Collimator number
coll$_s$ummary.dat u 1:3


0.01
0.001
0.0001
1e-005
Impact parameter
0
2
4
6
8
10
12
14
16
18
20
Collimator number

Reduced active length of secondary coll:



Goal: 0.1-0.2 %

As expected: **Active length of secondary collimator is much more critical**!

Collimation Counting Rates

1. Collimation (basic definitions):

$$n_{primary} * \eta = n_{tertiary}$$

$n_{primary}$: *impact rate on primary collimator;* η: *collimation inefficiency;* $n_{tertiary}$: *loss rates at aperature limitation*

2. Losses at collimation:

$$n_{col} = n_{prim}(1-\eta) = \sum_{i=1}^{4} N_{primary\ i} * \alpha_i + \sum_{i=1}^{16} N_{secondary\ i} * \beta_i$$

n_{col}: *loss rate at collimators;* $N_{primary}$, $N_{secondary}$: *counting rates at the collimator monitors,* α, β: *monitor sensitivity*

3. Losses at other locations:

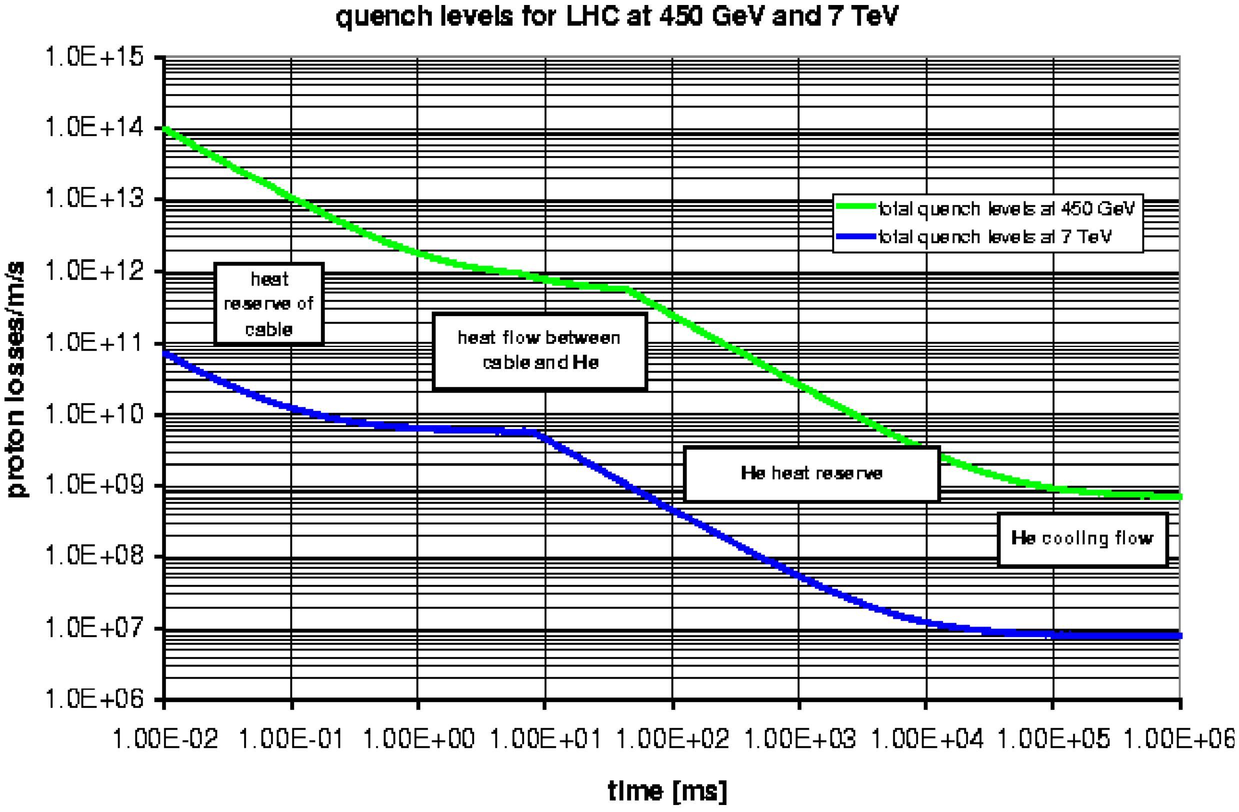
$$n_{tertiary} = n_{col} \frac{\eta}{1+\eta} = \sum_{i=1}^{N} quench\,level_i * \overline{safety}$$

$\overline{safety}$: *ratio of maximal safe losses to quench level; N: number of locations where losses will occur*

4. Aim of collimation: measure losses at collimation to avoid quenches and damages
   (aimed predict accuracy of quench levels with an error of 2)

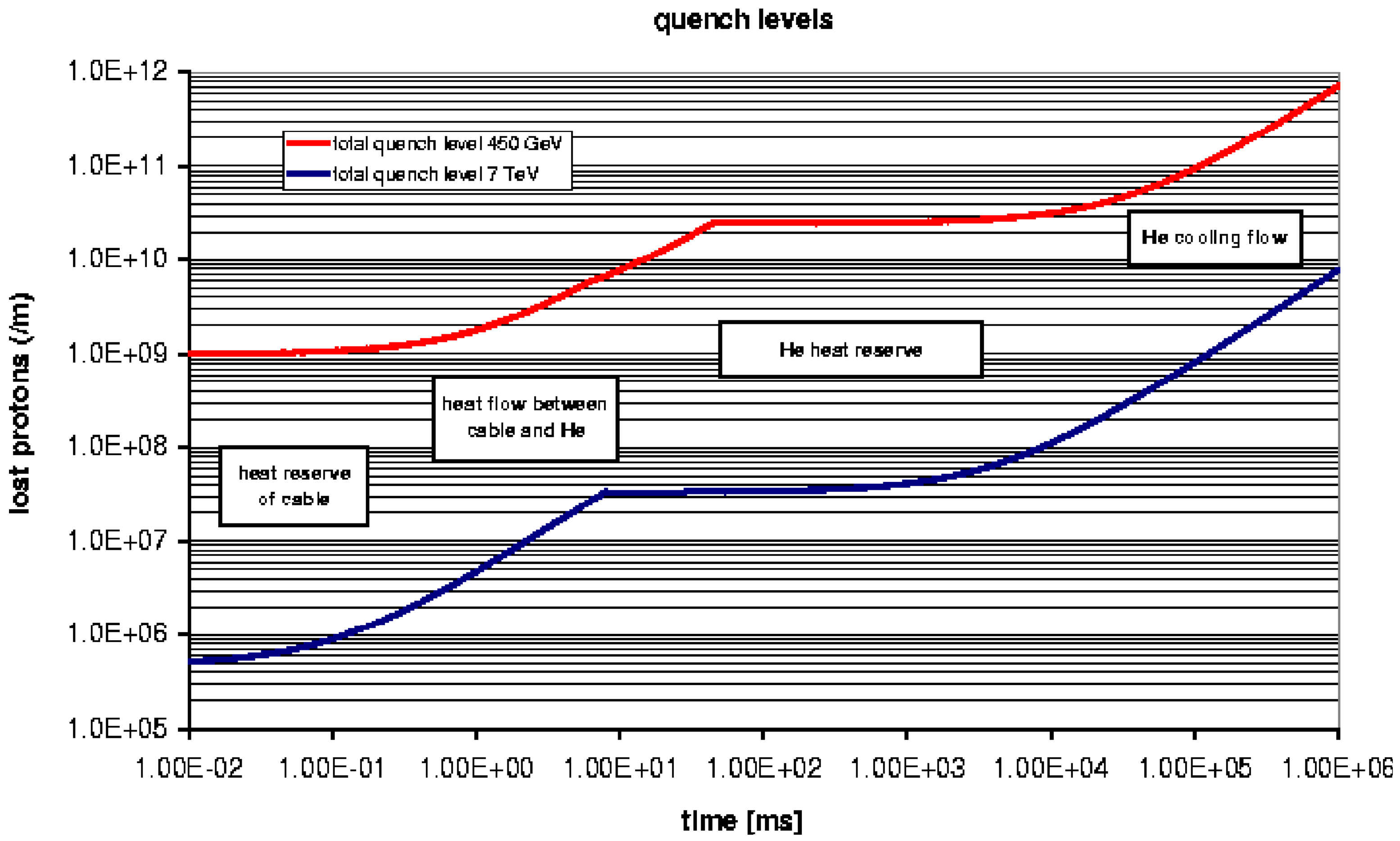
Quench Level Rates

1. MB bending magnet quench level rates Lit.: B. Jeanneret, LHC Project Report 44
2. Rates depend strongly on duration of losses
3. non linear rate change between injection and top energy



Quench Levels

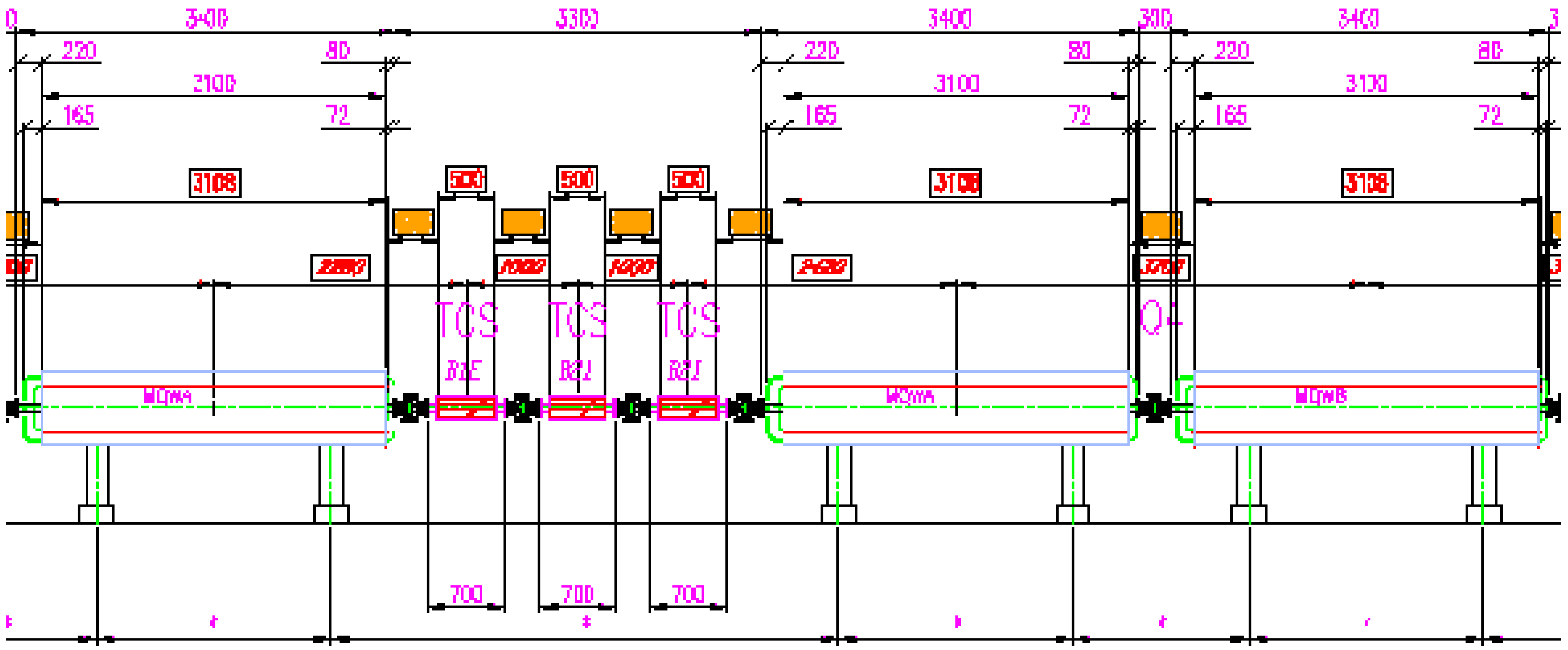
same plot as on previous transparency but in units of protons/meter



Proposed Collimator Locations IP7

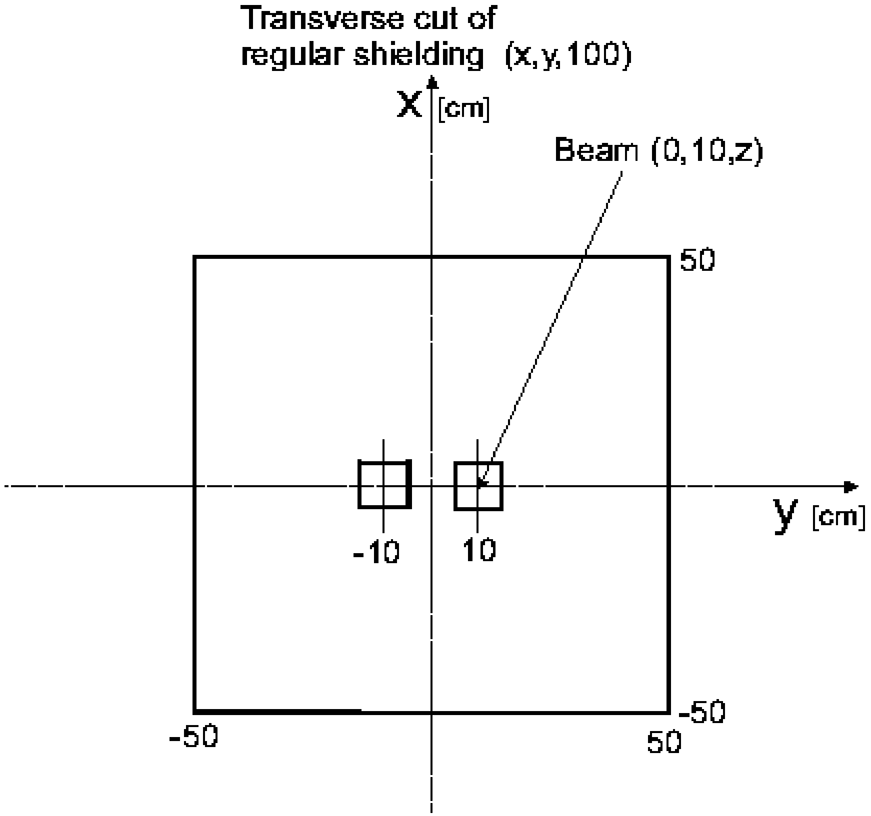
Collimators are about 1m apart and some arrangements are composed

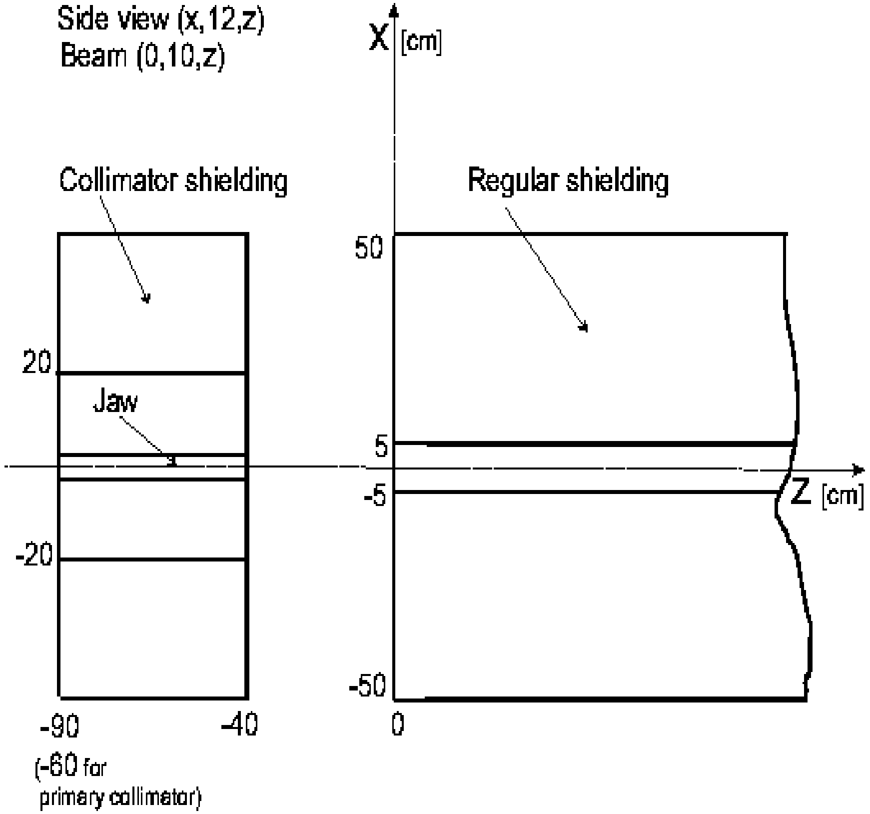
out of beam 1 and beam 2 collimators (distinction between losses of different beams will be not possible).



Shielding at Betatron Collimation

First layout of a IP7 shielding, the beam loss monitors are placed in the gap between collimator shielding and regular shielding

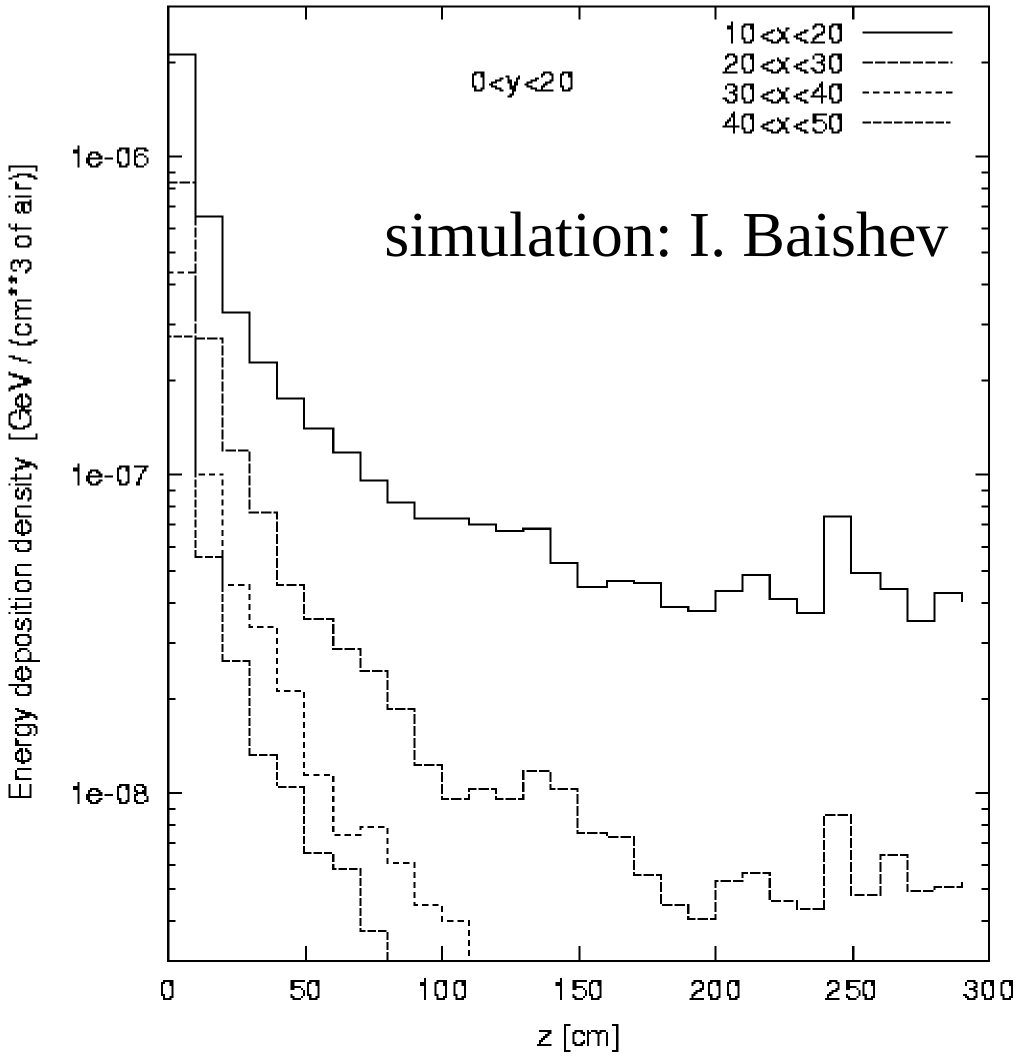




Longitudinal Energy Deposition

1. secondary particle energy deposition along the regular shielding
2. loss monitor location z=0
3. at 100 cm (location of foreseen second collimator in some arrangements) the energy deposition is only reduced by a factor of 10 (10<x<20)

Result: crosstalk between monitors, reduction of collimation adjustment accuracy=>
careful investigations needed



simulation: I. Baishev