PS Booster Studies with High Intensity Beams

Magdalena Kowalska
supervised by Elena Benedetto

Space Charge
Collaboration Meeting
20-21 May 2014

Outline:

1. High intensity beams in PS Booster
2. Motivations and proposal of PhD plans
3. History of the studies of collimation system in PSB
4. PS Booster collimation system for the future
5. Present case (50 MeV HI beam)
6. Studies of the future case (160 MeV HI beam)
7. Comments

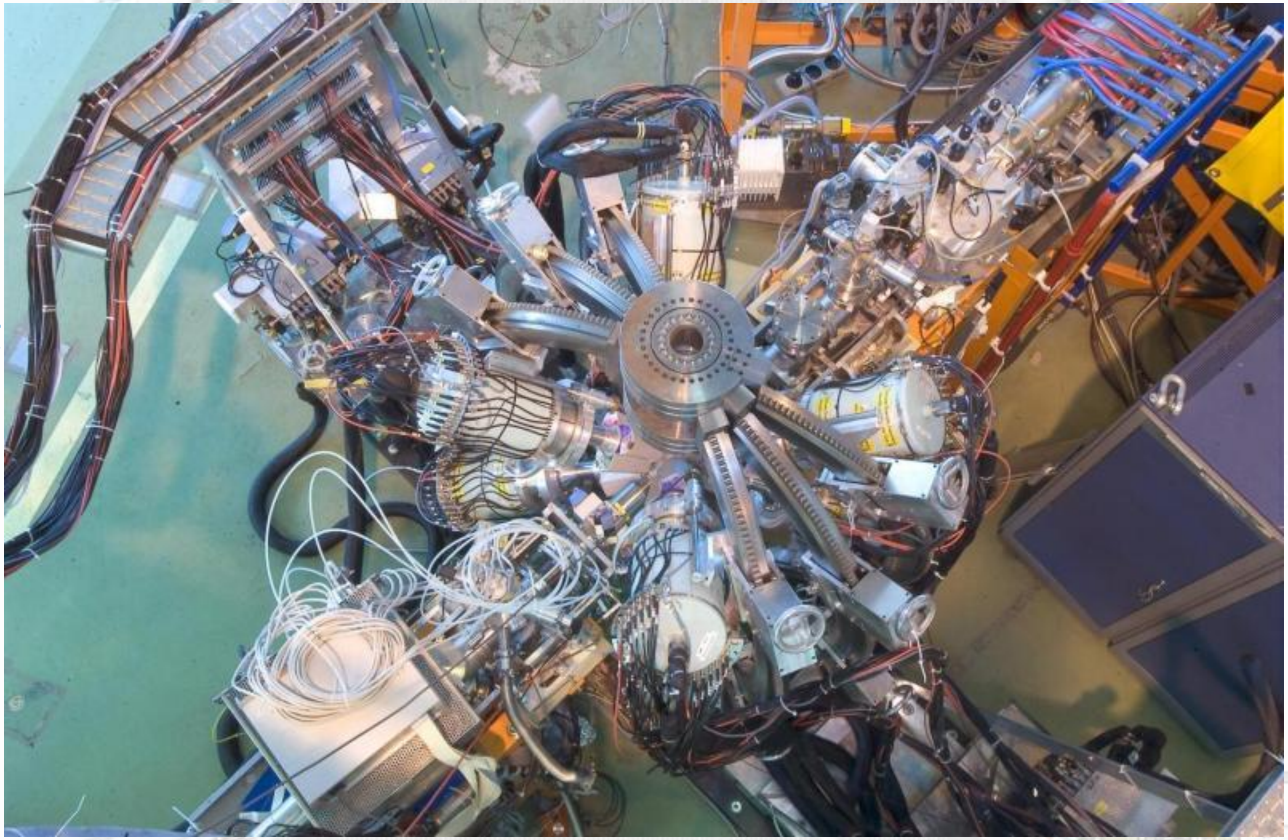
Outline:

1. High intensity beams in PS Booster
2. Motivations and proposal of PhD plans
3. History of the studies of collimation system in PSB
4. PS Booster collimation system for the future
5. Present case (50 MeV HI beam)
6. Studies of the future case (160 MeV HI beam)
7. Comments

High Intensity and Emittance Beams

i.e.
ISOLDE
Beam

(most
demanding
case)



Intensity
at the extraction
up to
1000 e+10

Normalized
extracted
horizontal
emittance
15 mm mrad
(max 1 sigma beam
size ~19.5 mm)

Normalized
extracted
vertical
emittance
10 mm mrad
(max 1 sigma beam
size ~21 mm)

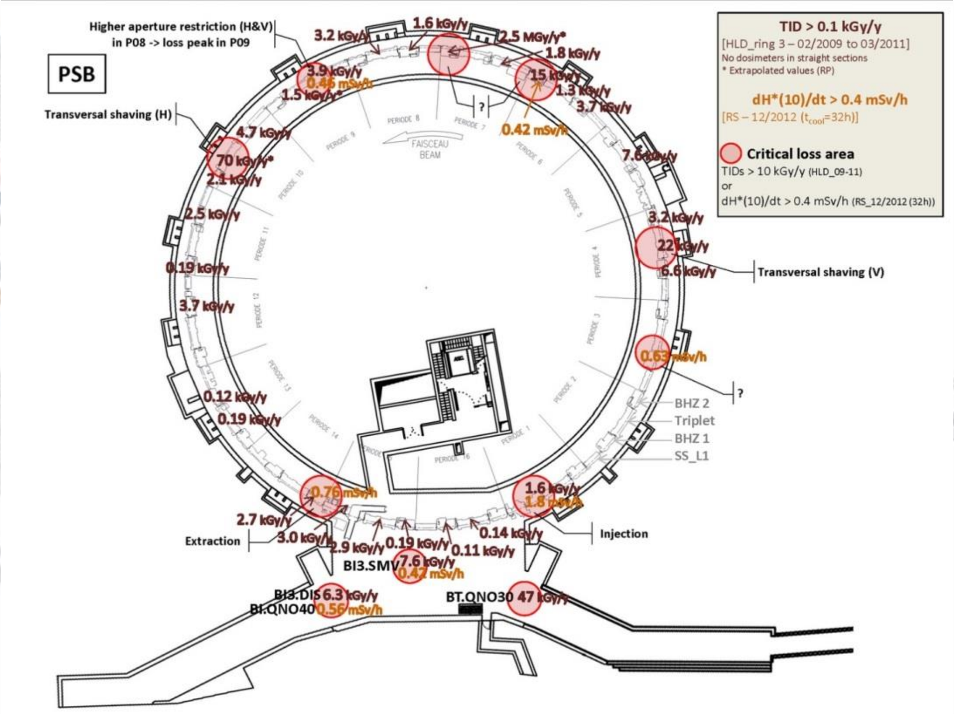
cause strong space charge effect on beam

Motivations

Radiation level is a concern in the PS Booster.

Increase of injection energy (from 50 MeV to 160 MeV) and beam intensity will cause more **harmful losses**.

Strategy is needed to mitigate the losses and control their locations.



"Analysis and control of beam losses in the PS Booster for high intensity beam"

Become familiar with the present beam loss pattern and activation mechanisms.

Reproduce the measurements at low energies, where space charge plays a major role.

Identify aperture, thickness, material of the absorber by physics considerations and simulations using

- PTC-(py)ORBIT (self consistent, containing collimation routine)

- SixTrack (track only halo particles, used to design LHC collimators)

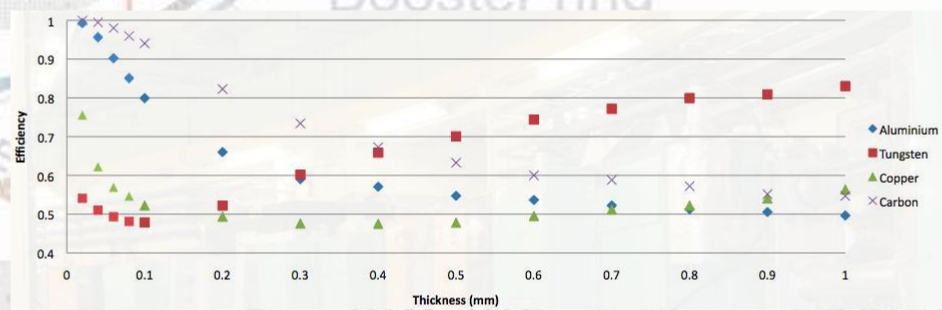
Investigate the feasibility and effectiveness of a collimation system (absorber).

Check weather the code's implemented physics model is valid for the energies of interest.

History of the studies of PS Booster Collimation System

Presently there is no collimation system in PS Booster

- Around 1995, first study was done by T. Trenkler and H. Schonauer on single turn system
- First investigations on collimation assuming (LHC like) multi turn approach (by student P. Jackson) showed that this design is not feasible for 160MeV
- The current idea is to build **a single pass collimator**
- And possible use existing **Window Beam Scope*** (aperture restriction) as an absorber

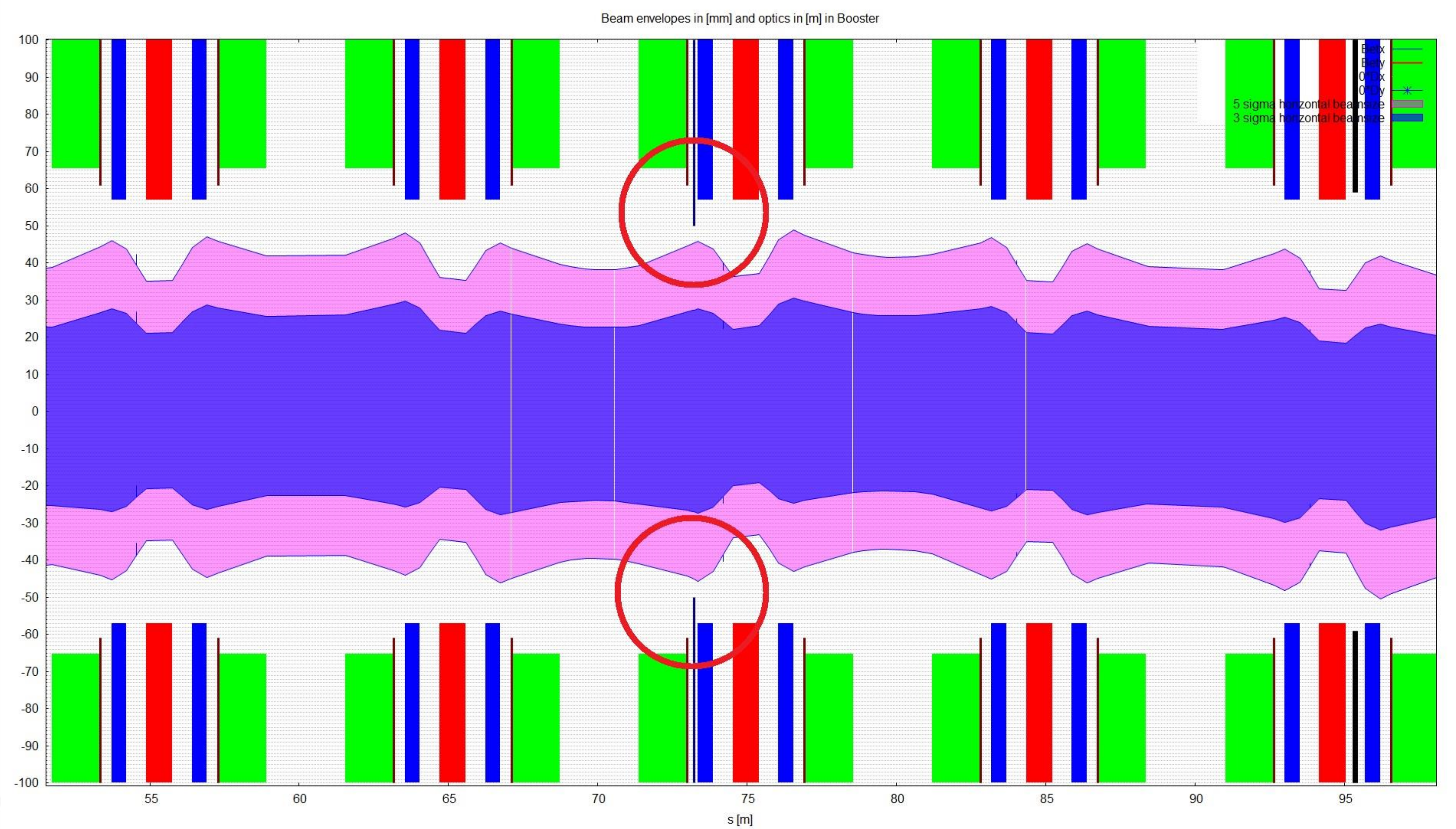


Efficiency (simplified model) for vertical loss at 160 MeV
(from a presentation by P. Jackson)
Very thin primary collimators (otherwise no multi turn behaviour), heating an issue

(from **Christian Carli "Beam Losses" at PSB H- Injection Review, 9th November 2011)**

Salvador Dali, Soft Watch at the Moment of First Explosion, 1954

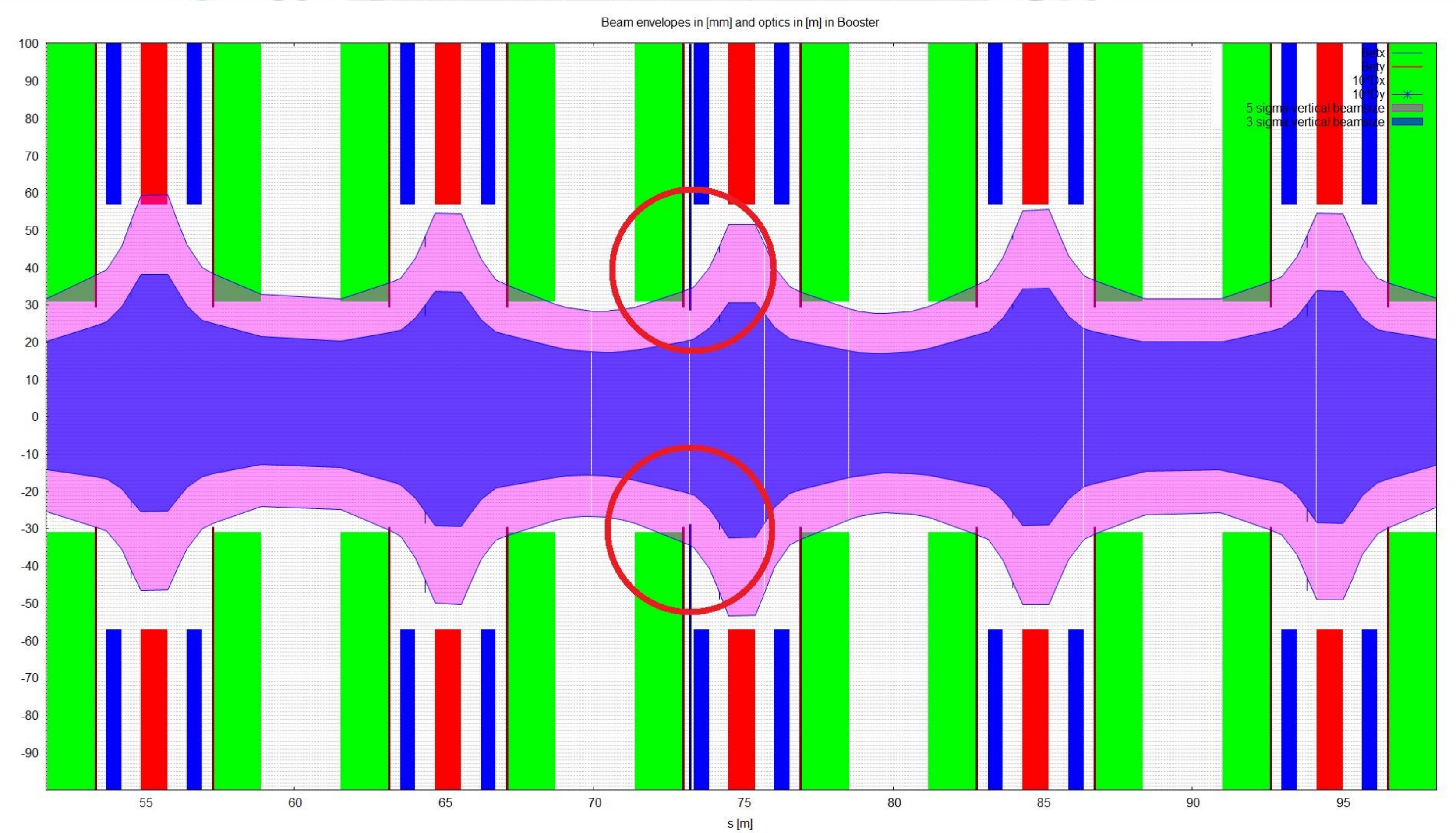
Horizontal aperture in present (50 MeV) case



Horizontal 3 and 5 sigma beam passing through PS Booster lattice with misalignment and field errors *calculated by Meghan McAteer* (MAD-X).

Losses are not foreseen in horizontal plane. (5 sigma) beam size is much smaller then the aperture restriction

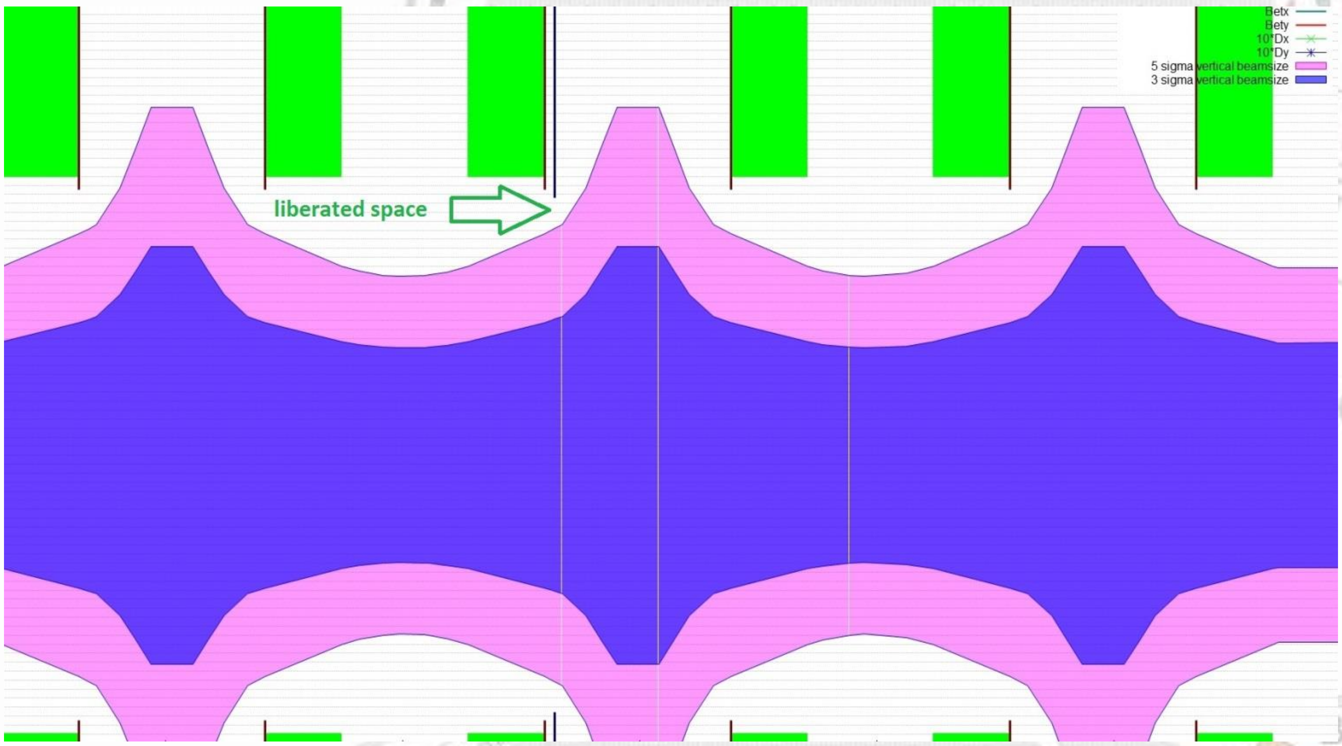
Vertical aperture in present (50 MeV) case



Horizontal 3 and 5 sigma beam passing through PS Booster lattice with misalignment and field errors *calculated by Meghan McAteer* (MAD-X).

Losses are expected in many locations only in vertical plane due to the similar size of the bend's scrapper and Window Beam Scope.

Vertical aperture in future (160 MeV) case

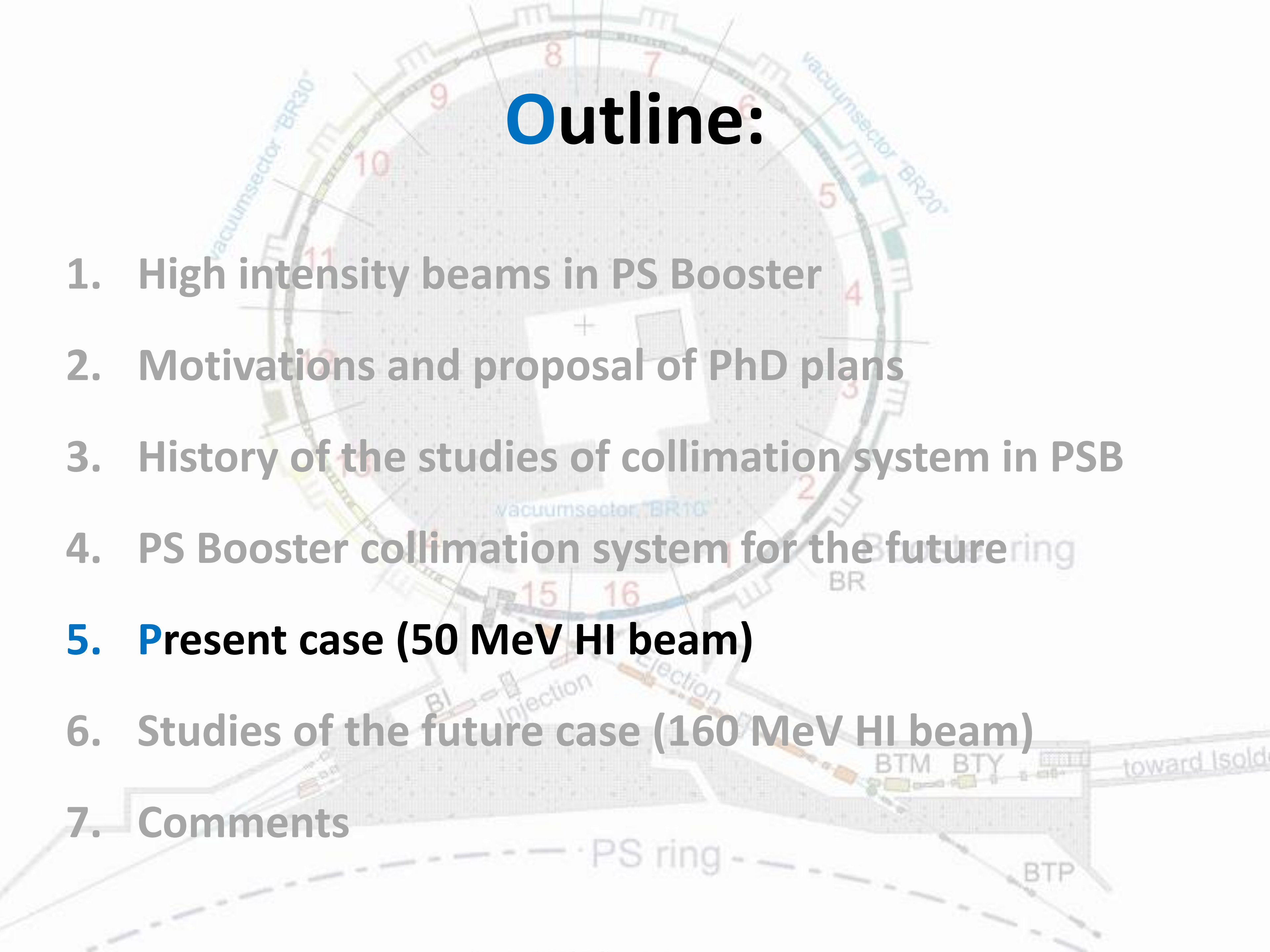


If similar normalized emittances needed at ejection.

Decrease of physical beam size.

Decrease of the machine acceptance possible.

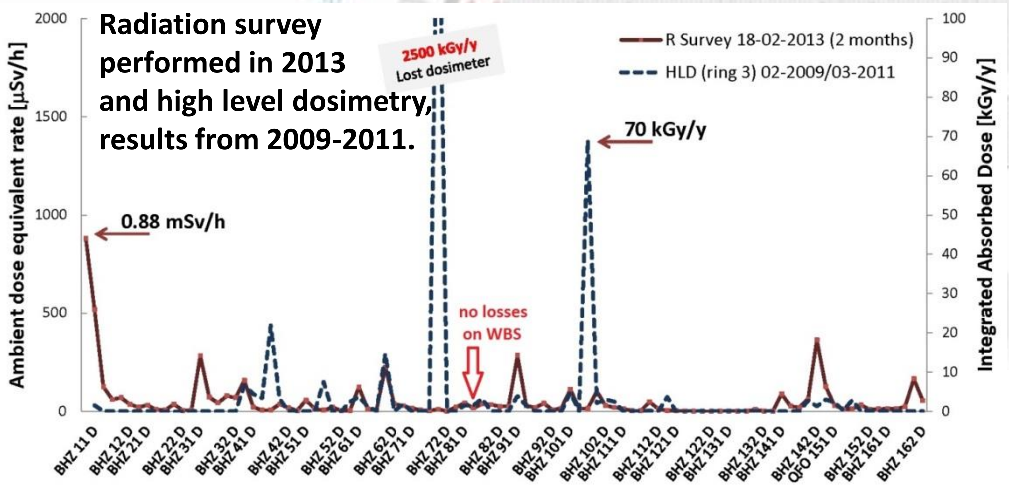
We can profit from this fact in order to plug a **collimation system**.



Outline:

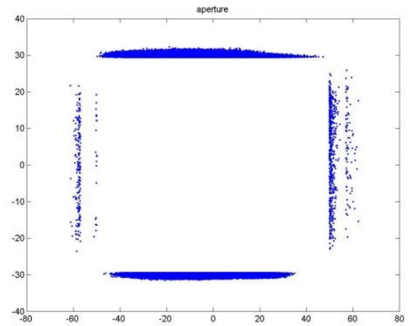
1. High intensity beams in PS Booster
2. Motivations and proposal of PhD plans
3. History of the studies of collimation system in PSB
4. PS Booster collimation system for the future
5. **Present case (50 MeV HI beam)**
6. Studies of the future case (160 MeV HI beam)
7. Comments

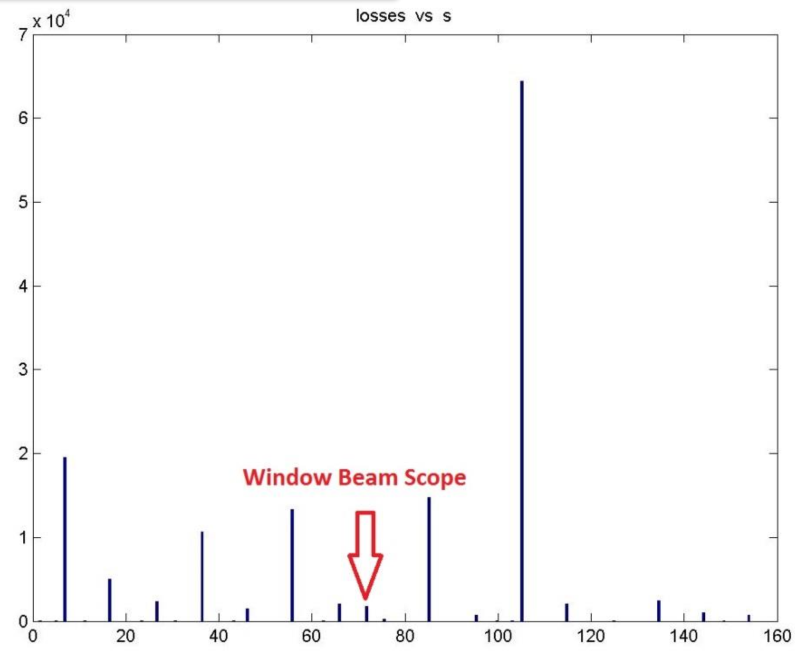
Better understanding of the nature of the present (50 MeV) case



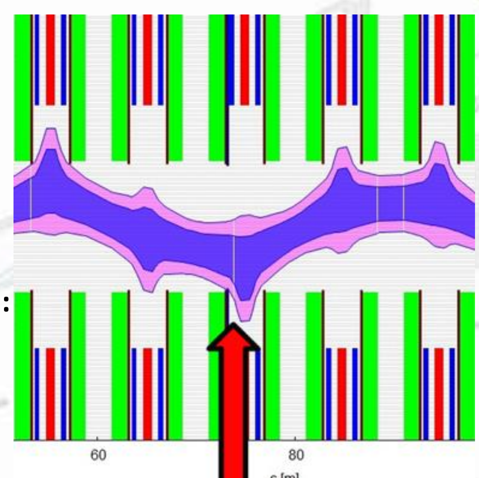
PSB – RS (18-02-2013 (2 months)) + HLD (09-10)

Aperture for the case with space charge on : losses are foreseen mostly in the vertical plane, which benchmarks with the predictions based on MAD-X optics calculations.





Example of shaving for LHC 50ns beam which also contributes to the losses generation:

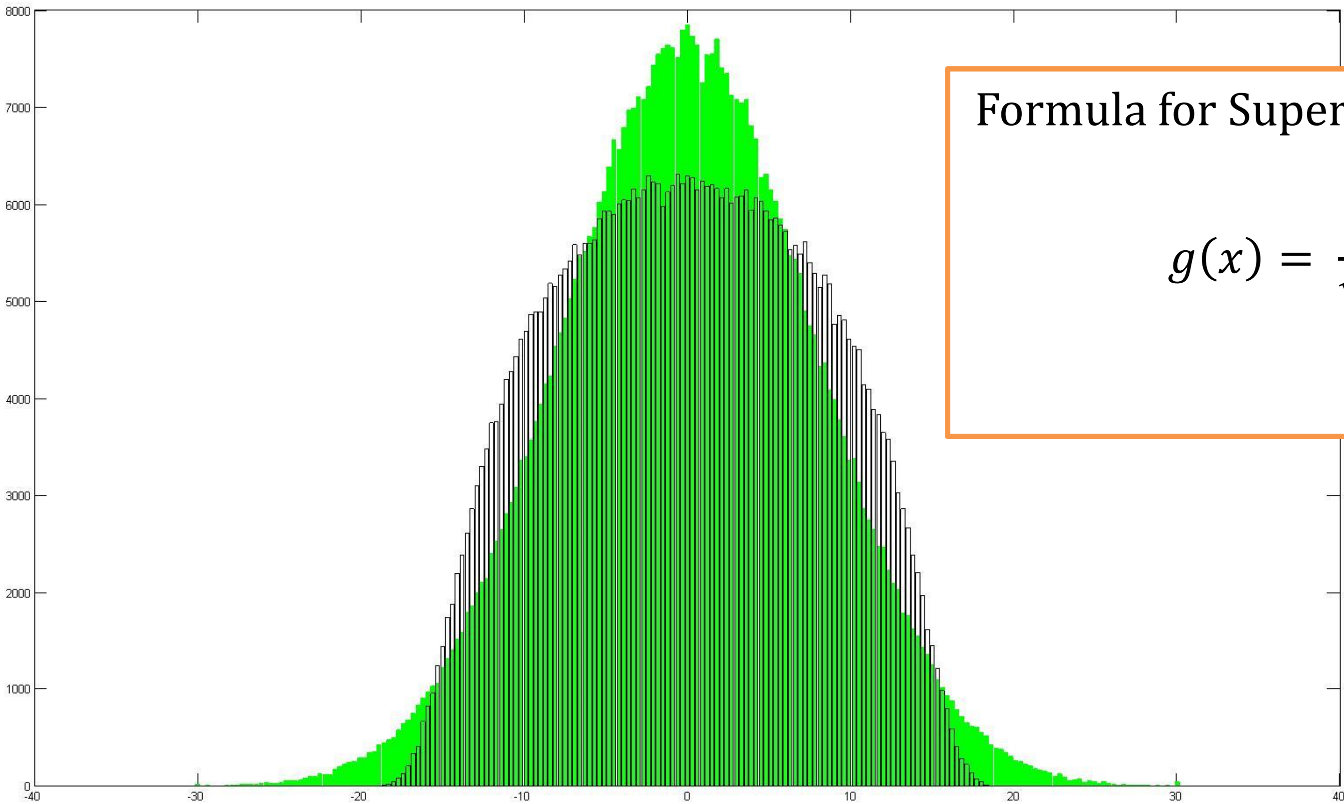


Outline:

1. High intensity beams in PS Booster
2. Motivations and proposal of PhD plans
3. History of the studies of collimation system in PSB
4. PS Booster collimation system for the future
5. Present case (50 MeV HI beam)
6. **Studies of the future case (160 MeV HI beam)**
7. **Comments**

Studies of the best beam profile (vertical plane), 160 MeV case

With the H- injection we will have the possibility to paint transverse profile of the beam.



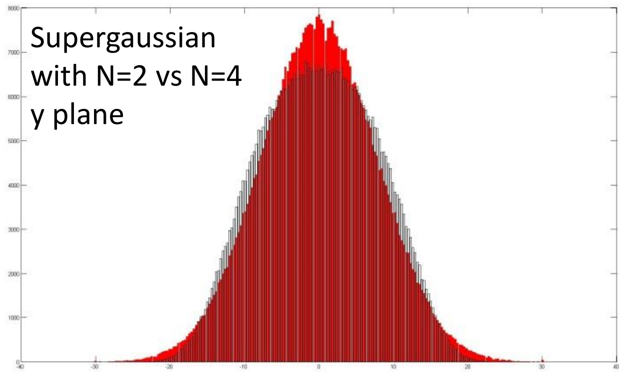
Comparison between Supergaussian distribution for N=10 (in bars) and N=2 (in green)

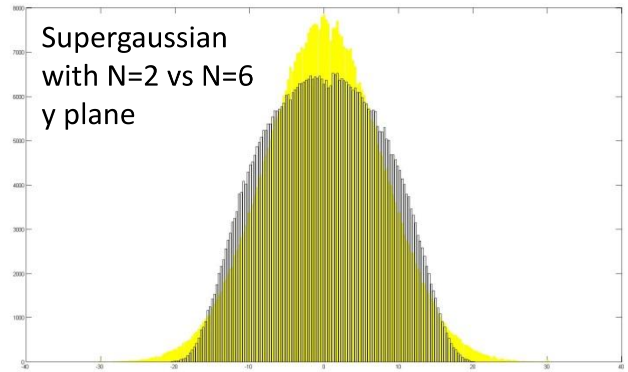
Formula for Supergaussian distribution:

$$g(x) = \frac{1}{\sqrt{2\pi}\,\sigma_0} exp\left(\frac{-(abs(x))^N}{2\sigma_0^N}\right)$$

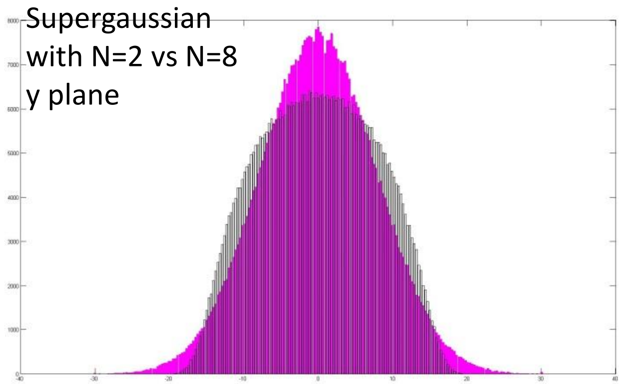
$$\text{with } \sigma = \sigma_0\left(\frac{\pi}{2}\right)^{\frac{2}{N}-1}$$

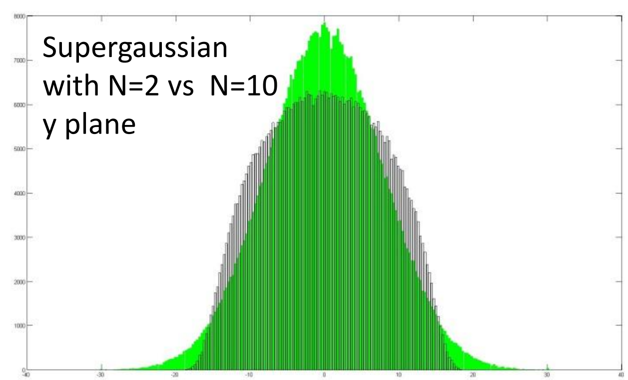
Studies of the best beam profile (vertical plane), 160 MeV case





Choice of the N parameter influence the beam profile shape.

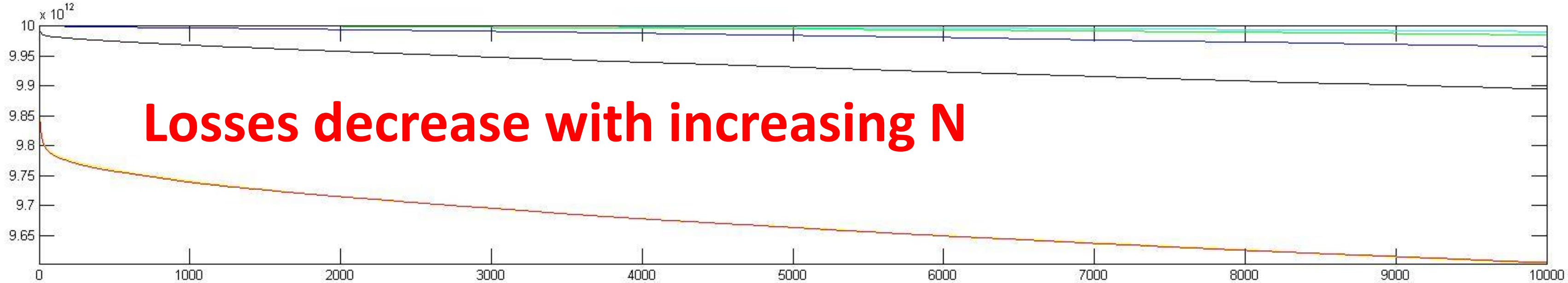




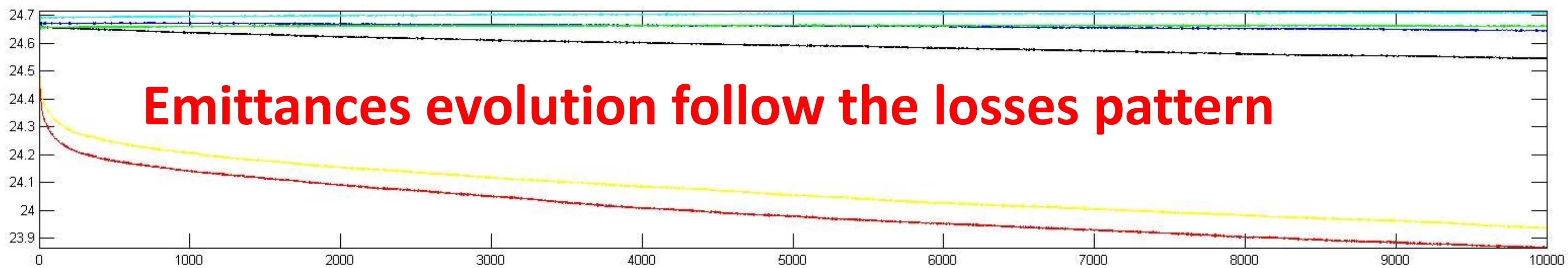
Distributions generated for different N with the same horizontal and vertical emittances.

Studies for different beam profiles

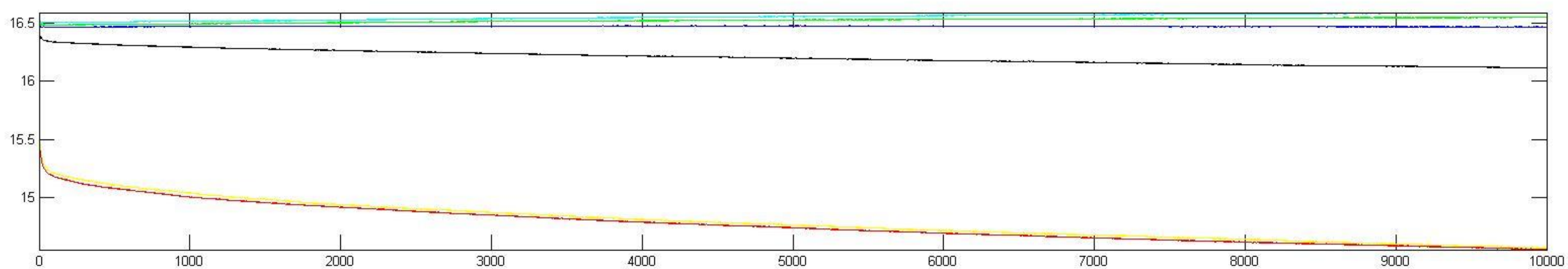
Intensity evolution



RMS horizontal emittance evolution



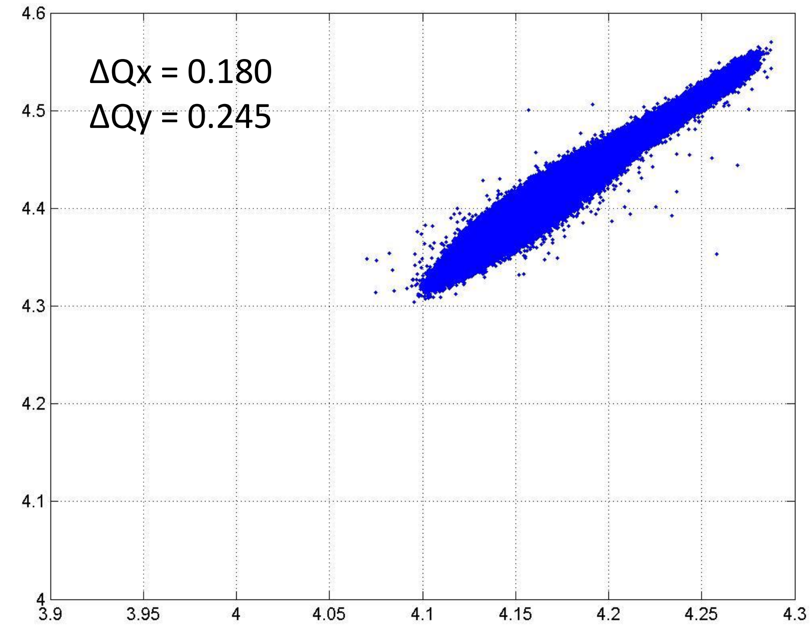
RMS vertical emittance evolution



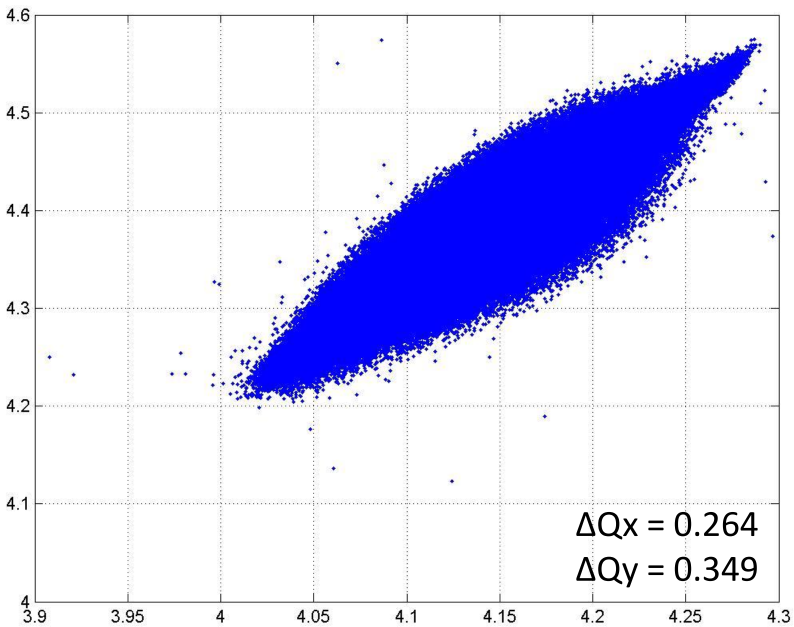
Legend:

standard Gauss
N=2
N=4
N=6
N=8
N=10

Tune spread as a function of beam profile (peak height), 160 MeV case

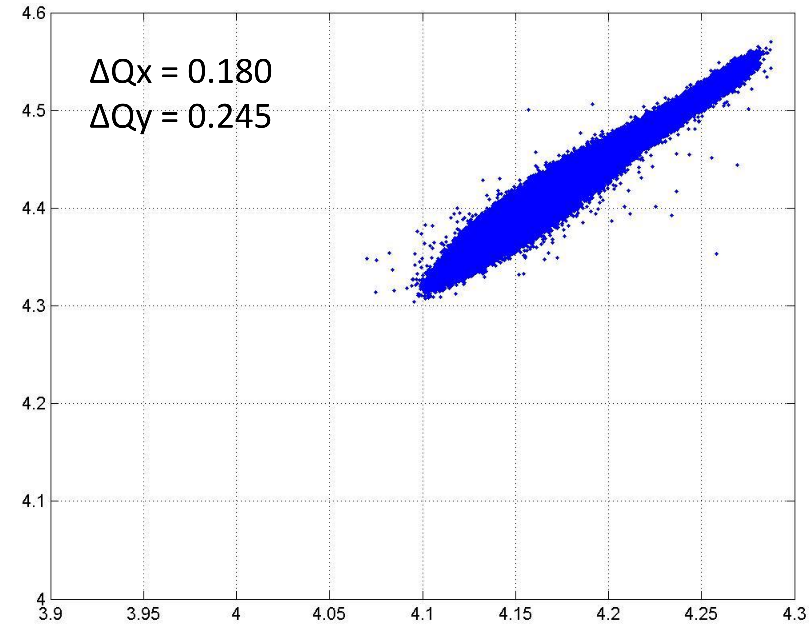


Tune footprint for Supergaussian N=10 at 160 MeV

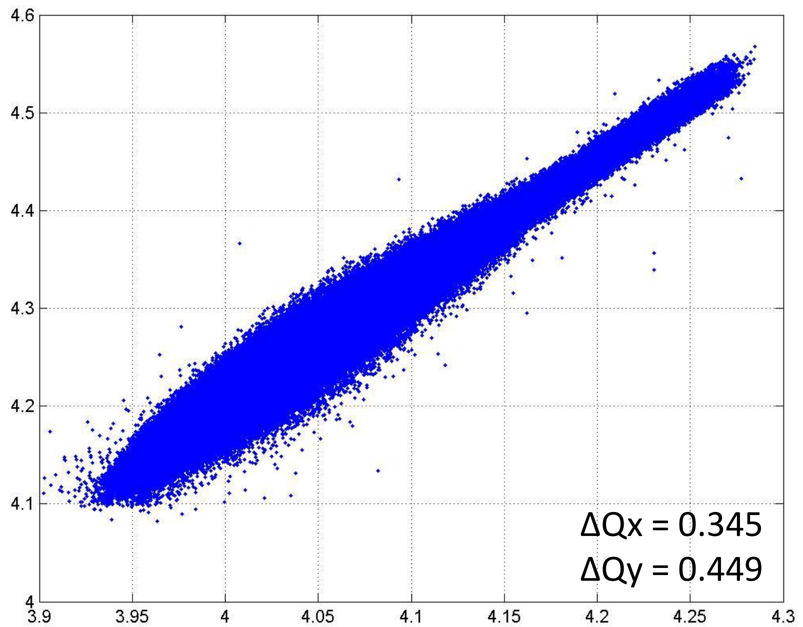


Tune footprint for Supergaussian N=2 at 160 MeV

Tune spread as a function of beam intensity (peak height), 160 MeV case



Tune footprint for Supergaussian N=10 at 160 MeV



Tune footprint for Gaussian N=10 at 160 MeV with double intensity

Comments:

- We are facing now a big challenge of **designing the collimation system for** PS Booster.
- Space charge is playing significant role in the dynamics and losses generation for high intensity beams in the PS Booster.
- First step is to understand the nature of the existing losses by measurements and simulations.
- This will allow us to make some predictions for the future 160 MeV high intensity beams.
- PTC-(py)ORBIT and SixTrack are the codes chosen for the studies.

- **Help from Space Charge community (and other experts) will be highly appreciated**

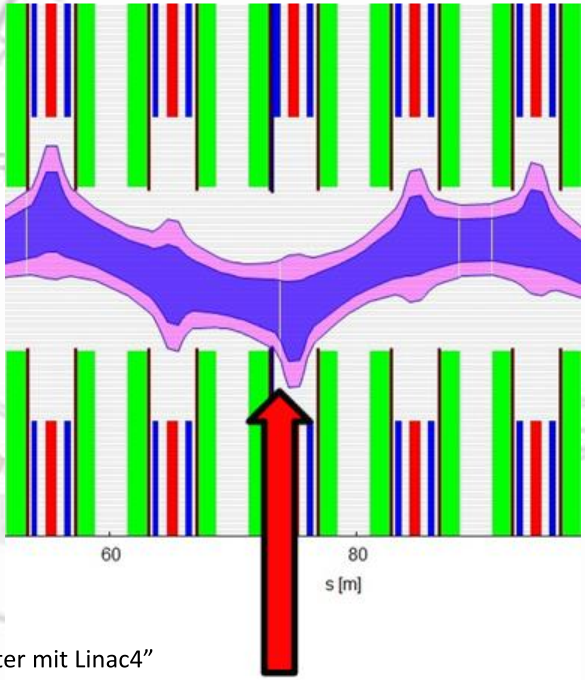
Thanks for your attention

New Window Beam Scope dimensions for 160 MeV

Is an aperture restriction in PS Booster designed in the past to perform beam profile measurements.

In current operation its main role is to shave the beam in order to have a controlled value of the intensity and emittances.

Example of shaving for LHC 50ns beam:



With injection energy upgrade…

physical size **50mm x 28.6mm** declared in .dbx MADX file should be scaled as

sqrt(bgam160/bgam50) ~= 1.35

Taking into account 5 mm of closed orbit distortion

the new WBS aperture should be
38.18mm x 22.40mm **

* * Matthias Scholz "Simulationen zur H- Charge Exchange Injection in den CERN Proton Synchrotron Booster mit Linac4"