Ion impact distributions of DS collimators in IP2

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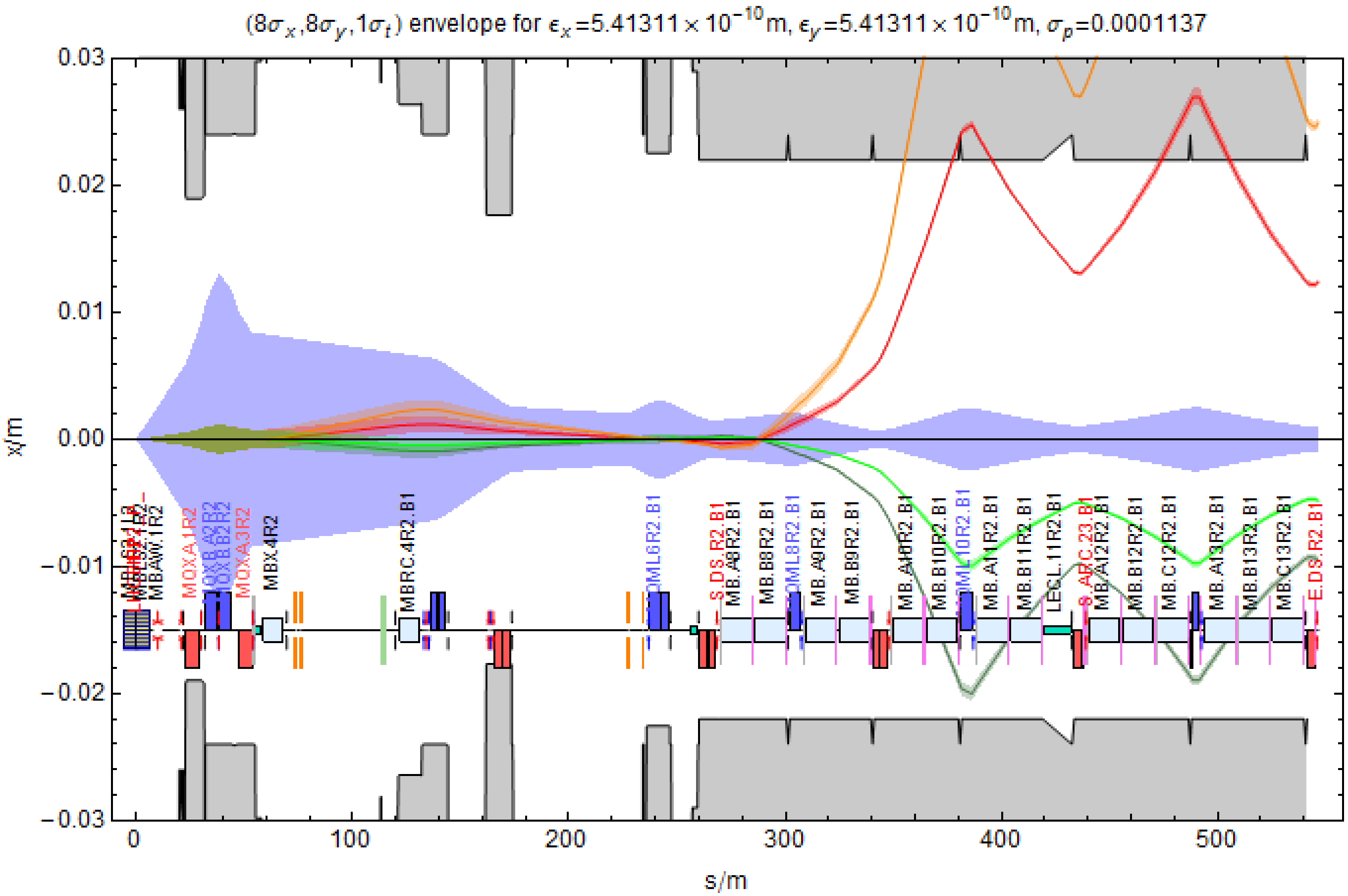
Motivation

Installation of collimators in the Dispersion Suppressor (DS) to both sides of ALICE (IP2) to intercept secondary beams from bound-free pair production (BFPP) and electromagnetic dissociation (EMD) .



Main: **208-Pb-82+**

BFPP1: **208-Pb-81+**

BFPP2: **208-Pb-80+**

EMD1: **207-Pb-82+**

EMD2: **206-Pb-82+**

The rigidity of each beam changed by

$$\delta = \frac{1 + \Delta m / m_{Pb}}{1 + \Delta Q / Q} - 1$$

General Procedure

Editing the sequence and add DS collimator in IP2.

↓

Calculating the **transfer matrix** form IP to front of collimator with MADX.

↓

Generation of the distribution at the IP. ↓ **Tracking of distribution** to front of collimator.	Calculate σ-Matrix at IP. ↓ **Tracking of σ-Matrix** to front of collimator.

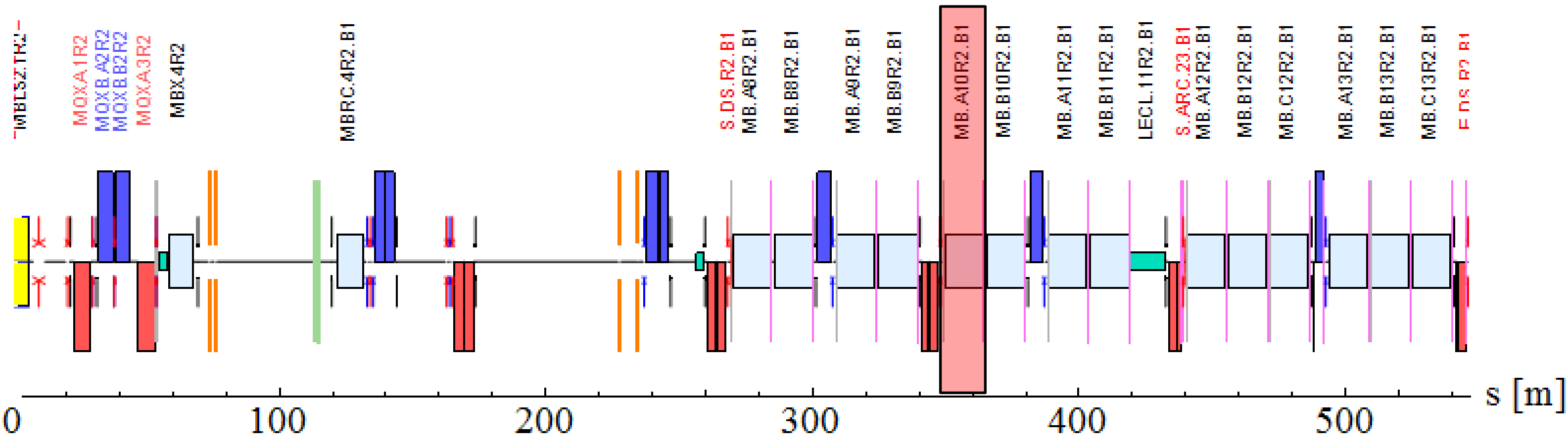
↓

Convert MADX output into **desired format for FLUKA**.

Editing the sequence

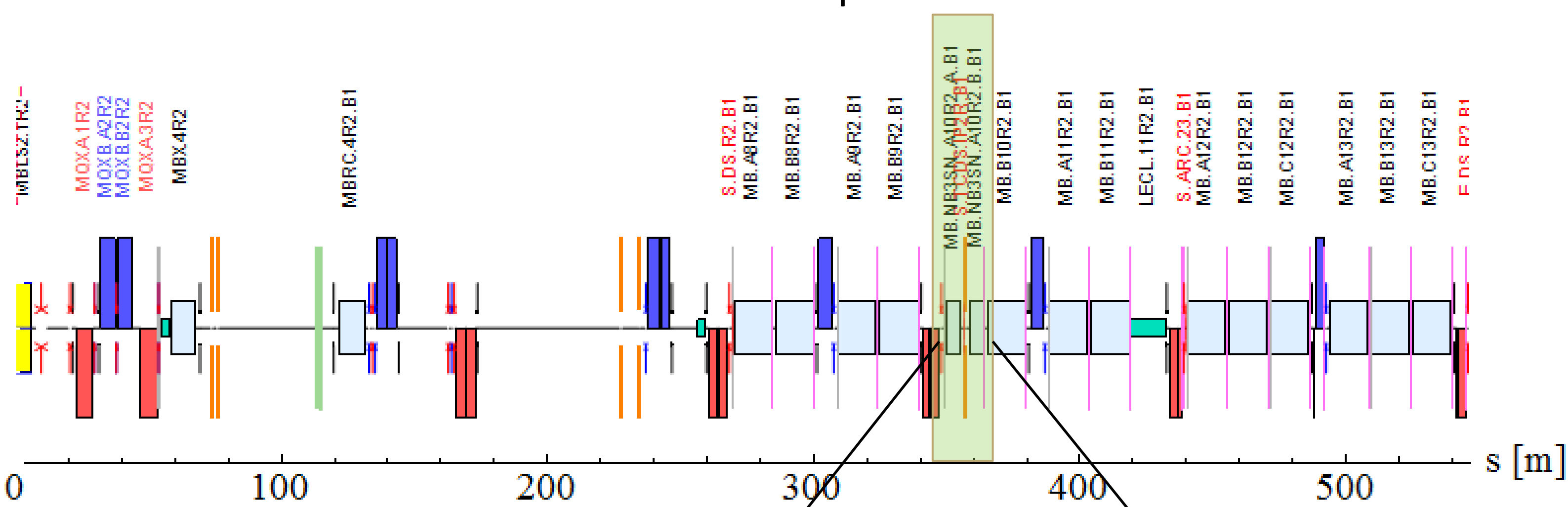
Magnet to be replaced **MB.A10R2**

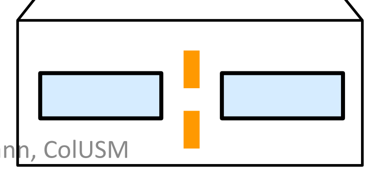
Nominal Beam Line



IP2

Modified Sequence



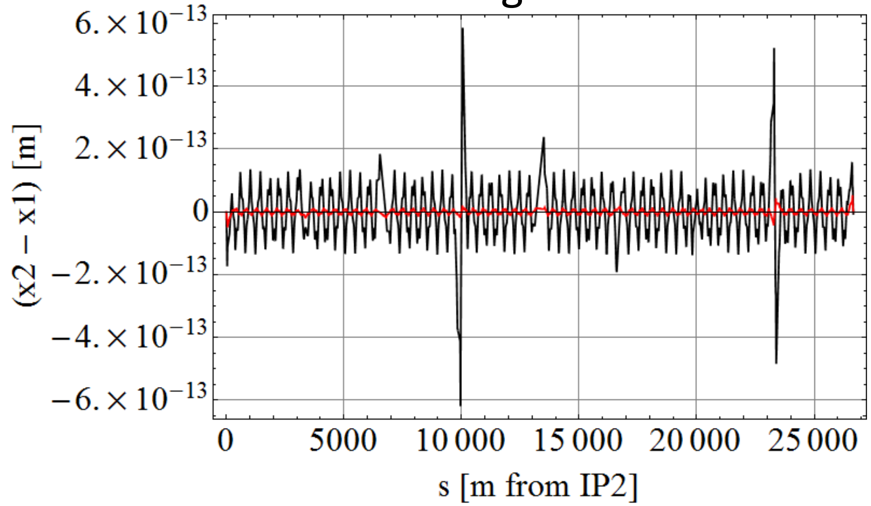


2 × 11T dipole with L = 5.3m

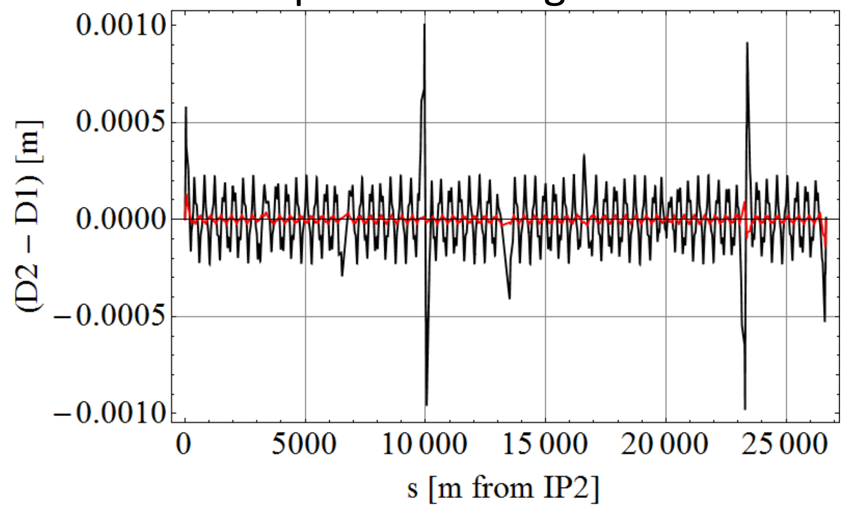
Collimator jaw with L = 1m

Editing the sequence – Influence on Optics

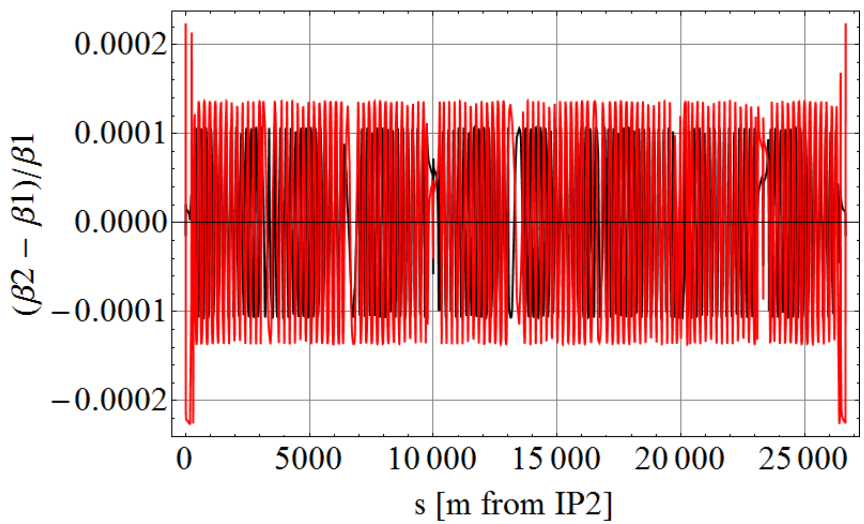
Orbit change in X and Y



Dispersion change in X and Y



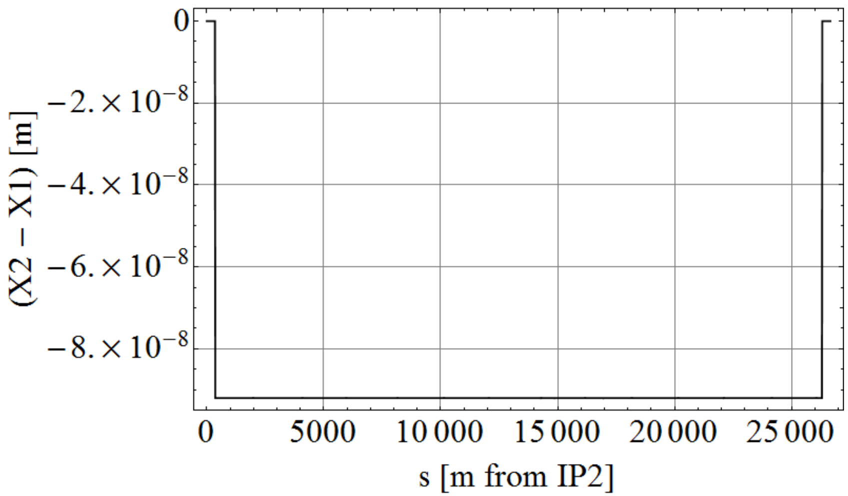
β-Beat in X and Y

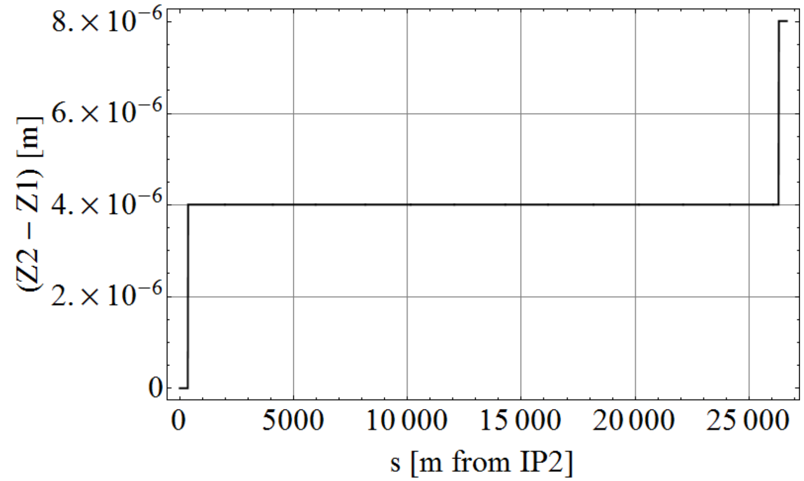


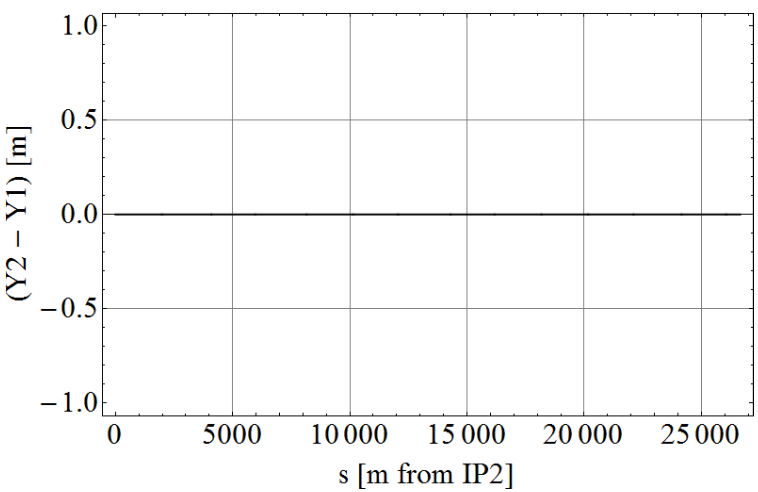
Without taking magnet errors into account the changes in the optics are very small.

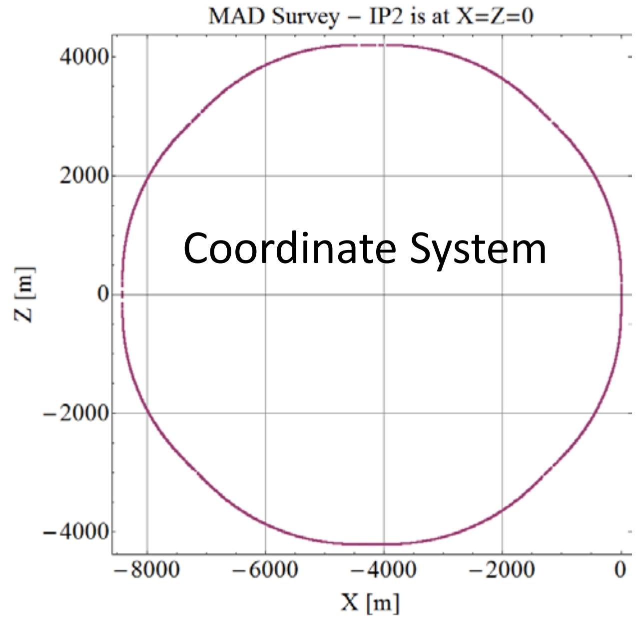
Editing the sequence – Influence on Optics

MADX Survey









Transfer Matrix

Do TWISS with initial conditions at the IP and RMATRIX flag on:

→ $\delta p = \delta p_{BFPP}$, $\beta_{x,y}$, $\alpha_{x,y}$, x, y, px/(1+δ), py/(1+δ)

with $\beta_{x,y}$, $\alpha_{x,y}$, x, y, px, py of the main beam orbit at IP2.

This generates TWISS table with transfer matrix elements after each element in the sequence.

MADX 6D Transfer Matrix:

→ form IP2 @ s = 0m

→ to new front plane of collimator @ s = 356.27m

Tracking

A.)

Generate **coordinates** for each particle at IP and track them with transfer matrix M:

$$\boldsymbol{x}_{coll} = \boldsymbol{x}_{co,coll} + \mathrm{M} \cdot \boldsymbol{x}_{IP2}$$

where $\boldsymbol{x}$ = *(x, px, y, py, t, pt)*
and M = (6 × 6) transfer matrix

B.)

Calculate **σ-Matrix** at IP and track envelope:

$$\sigma_{coll} = \mathrm{M} \cdot \sigma_{\mathrm{IP}} \cdot \mathrm{M}^{\mathrm{T}}$$

where M = (6 × 6) transfer matrix and

$$\sigma = \begin{pmatrix} \sigma_x & 0 & 0 \\ 0 & \sigma_y & 0 \\ 0 & 0 & \sigma_t \end{pmatrix} \qquad \sigma_{x,y,t} = (2 \times 2)$$

A.) Generating distribution @ IP

R. Bruce et al., *Beam losses from ultraperipheral nuclear collisions between 208Pb82+ ions in the Large Hadron Collider and their alleviation*, Phys. Rev. ST Accel. Beams 12, 071002 (2009)

Generate x_0, x'_0 & y_0, y'_0

Assume Gaussian Distribution of the main beam:

$$f_\beta(x_0, x'_0) = \frac{N_b \beta_0}{2\pi\sigma_0^2} \exp\left(-\frac{x_0^2 + (\alpha_0 x_0 + \beta_0 x'_0)^2}{2\sigma_0^2}\right)$$

Distribution of collision point at the IP:

$$\lambda(x_0, x'_0) = \frac{\beta_0}{\sqrt{2}\pi\sigma_0^2} e^{-\frac{2x_0^2 + (\alpha_0 x_0 + \beta_0 x'_0)^2}{2\sigma_0^2}}$$

→ Gaussian distribution with smaller standard deviation $\sigma_{\lambda,0}$.
→ The standard deviation of the angular distribution $\sigma_{p,0}$ is similar to the main beam.

$$\sigma_{\lambda,0} = \left(\int x_0^2 \, \lambda(x_0, x'_0) \, dx'_0 \, dx_0\right)^{1/2} = \frac{\sigma_0}{\sqrt{2}} \qquad \sigma_{p,0} = \sqrt{\frac{\epsilon}{\beta_0} \frac{2 + \alpha_0^2}{2}}$$

A.) Generating distribution @ IP

MAD canonical momentum is: $p_t = \frac{E - E_0}{p_0 c}$

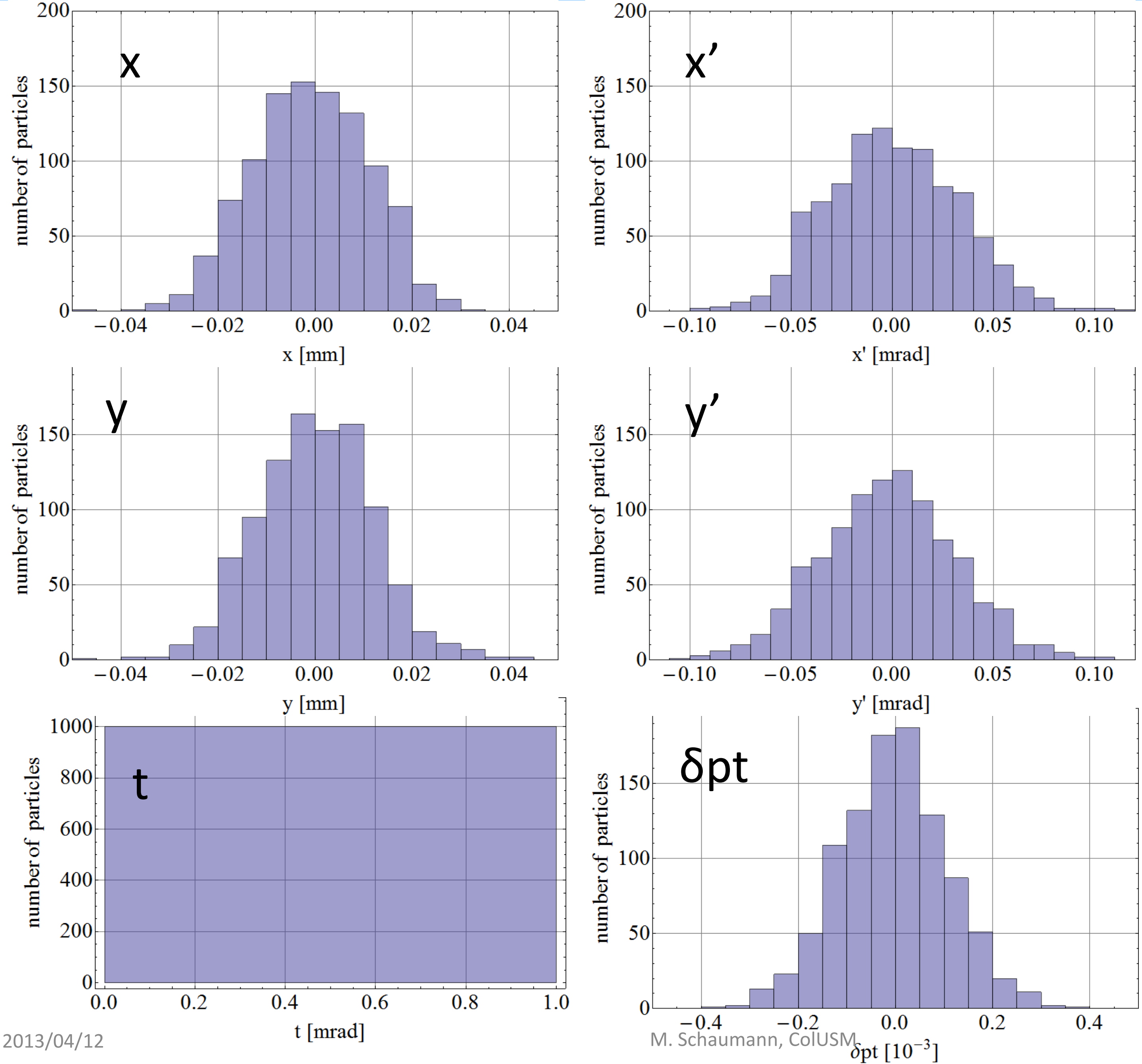
Generate t_0, pt_0

where $p_0 = (6.5Z\ \text{TeV})(1+\delta)$

- The longitudinal positions of the particles are not important for this analysis, since **the impact point (front plane of the collimator) is fixed** for this first attempt:
  → set them all to ***t = 0*** at the IP.

- Assume that the ***pt*** values are Gaussian distributed around <pt>=0 at the IP,
  → take the change in rigidity into account when generating the transfer matrix for a beam with a given $\delta \neq 0$.

A.) Generating distribution @ IP



Example coordinates of 1000 particles at the IP

B.) Calculate σ-Matrix @ IP

Distribution of collision point at the IP:

$$\lambda(x_0, x_0') = \frac{\beta_0}{\sqrt{2}\pi\sigma_0^2} e^{-\frac{2x_0^2+(\alpha_0 x_0+\beta_0 x_0')^2}{2\sigma_0^2}}$$

σ-Matrix @ IP:

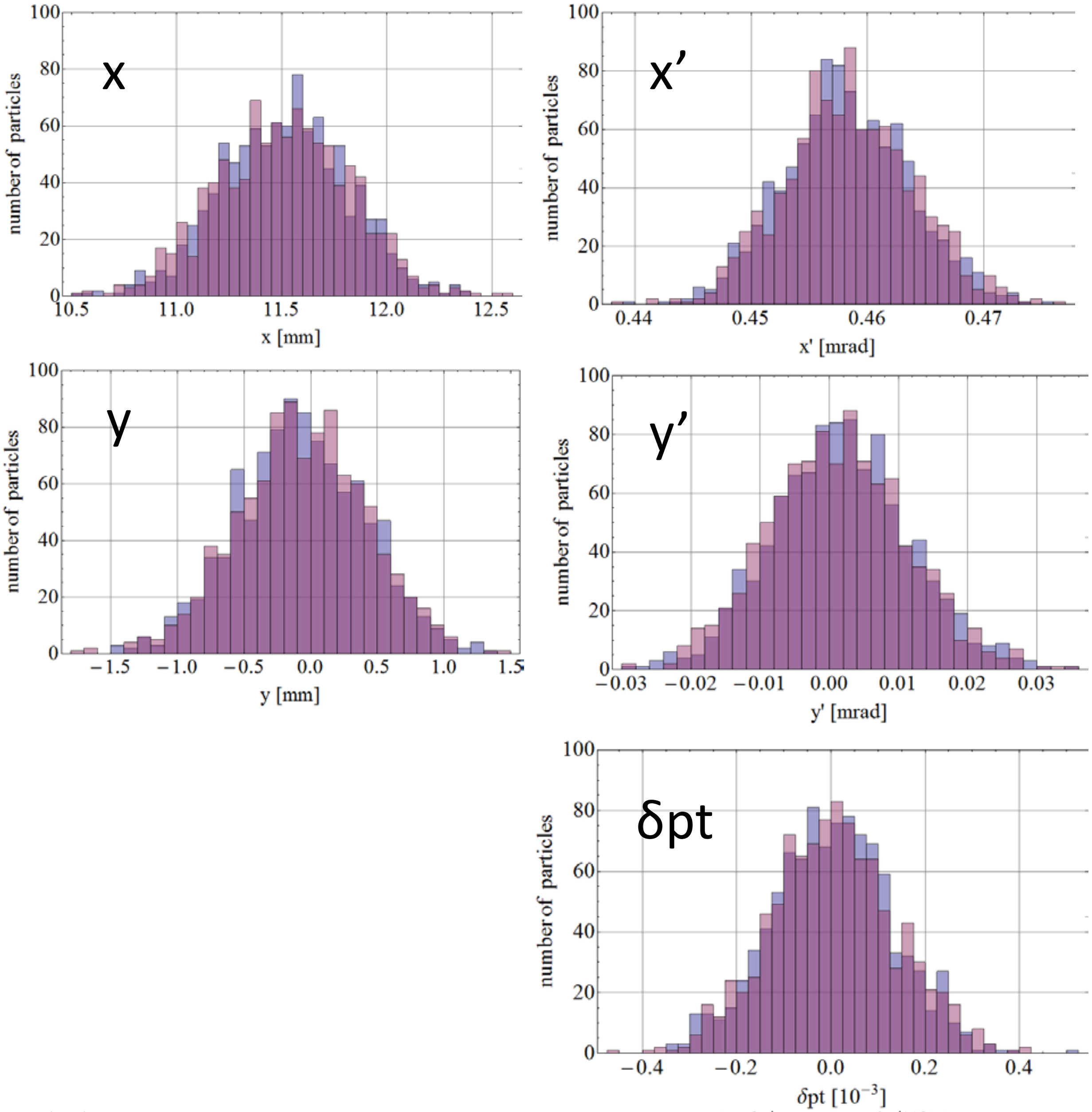
$$\sigma_x(IP) = \begin{pmatrix} <x^2> & <x\,x'> \\ <x'x> & <x'^2> \end{pmatrix} = \begin{pmatrix} \frac{\epsilon\beta_x}{2} & -\frac{\epsilon\alpha_x}{2} \\ -\frac{\epsilon\alpha_x}{2} & \frac{\epsilon(2+\alpha_x{}^2)}{2\beta_x} \end{pmatrix}$$

where $<x^2> = \int x^2 \lambda(x_0, x_0') dx$ and $\sigma_0 = \sqrt{\epsilon\beta}$

$$<x'^2> = \int x'^2 \lambda(x_0, x_0') dx'$$

$$<xx'> = \int xx' \lambda(x_0, x_0') dx dx'$$

Tracking Results



Example coordinates of 1000 particles at the collimator:

A.)Coordinate

B.) σ-Matrix

Tracking

Coordinates for B.)

Generate Gaussian distributions with mean = orbit coordinates, std. dev.= σ-matrix diagonal elements.

Tracking Results

Mean of tracked Coordinates :

$$\begin{pmatrix} x \\ x' \\ y \\ y' \\ t \\ p_t \end{pmatrix} = \begin{pmatrix} 11.51 \\ 0.46 \\ -0.07 \\ 1.1\times10^{-3} \\ 1.36 \\ 5.1\times10^{-3} \end{pmatrix} \times 10^{-3}$$

Standard Deviation of tracked Coordinates :

$$\begin{pmatrix} \sigma_x \\ \sigma_{x'} \\ \sigma_y \\ \sigma_{y'} \\ \sigma_t \\ \sigma_{pt} \end{pmatrix} = \begin{pmatrix} 3.2 \\ 5.5\times10^{-3} \\ 0.5 \\ 9.9\times10^{-3} \\ 9.3\times10^{-3} \\ 0.13 \end{pmatrix} \times 10^{-3}$$

Coordinates of the orbit for a beam with δp = δpBFPP at the collimator:

$$\begin{pmatrix} x \\ x' \\ y \\ y' \\ t \\ p_t \end{pmatrix} = \begin{pmatrix} 11.51 \\ 0.46 \\ -0.06 \\ 1.0\times10^{-3} \\ 0 \\ 0 \end{pmatrix} \times 10^{-3}$$

Diagonal Elements of σ-matrix at the collimator :

$$\begin{pmatrix} \sigma_x \\ \sigma_{x'} \\ \sigma_y \\ \sigma_{y'} \\ \sigma_t \\ \sigma_{pt} \end{pmatrix} = \begin{pmatrix} 3.0 \\ 5.3\times10^{-3} \\ 0.5 \\ 9.8\times10^{-3} \\ 8.9\times10^{-3} \\ 0.13 \end{pmatrix} \times 10^{-3}$$

$$\sigma_{x,\sigma} / \sigma_{x,coord} = \begin{pmatrix} 0.95 & 0.96 & 0.99 & 0.98 & 0.96 & 0.98 \end{pmatrix}$$

Conversion to FLUKA input

- Positions and angles on collimator:
  - x, x', y, y' taken as calculated above in units of 10^{-3}.
  - t = s = 356.27m (collimator front plane) for all particles.
- pt → Energy E

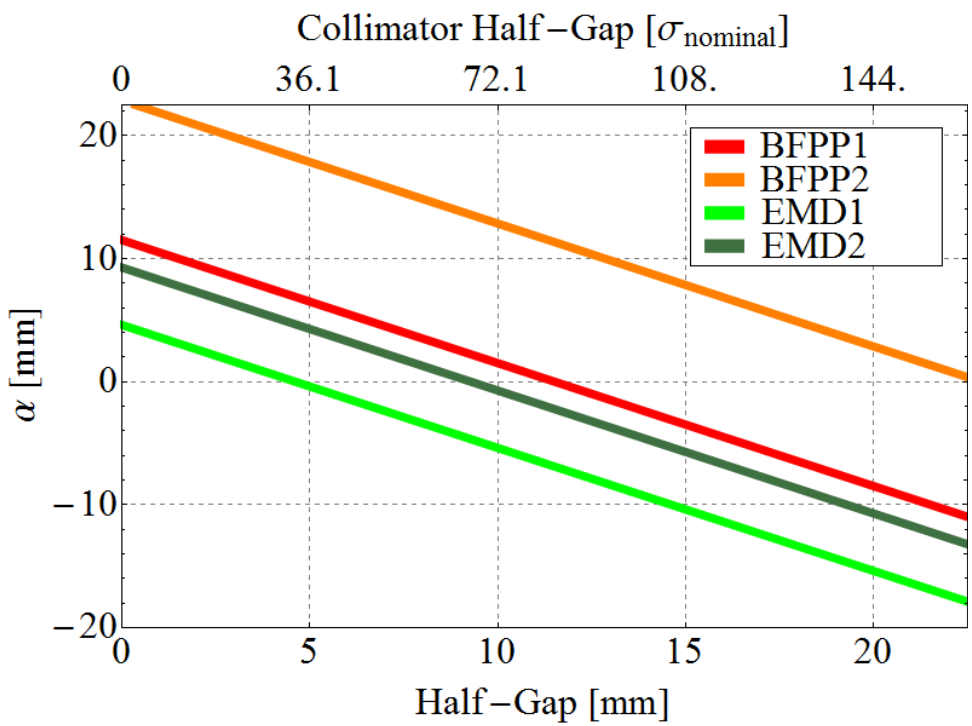
$$E = \sqrt{m^2c^4 + p^2c^2}$$

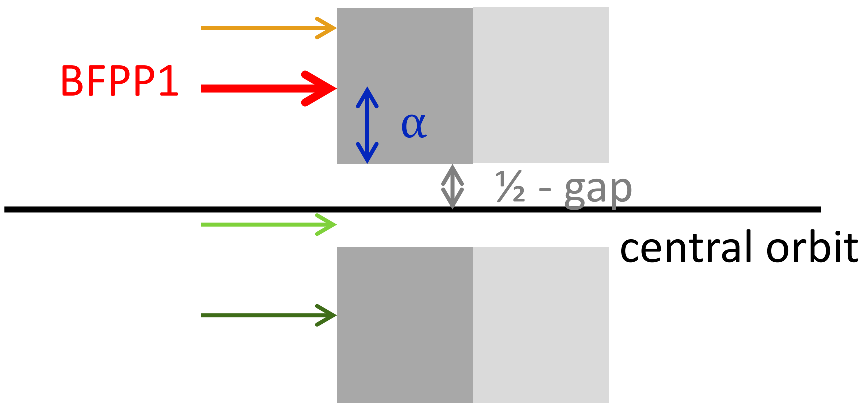
$$p_{Pb} \rightarrow p_{Pb}(1+\delta_p)(1+\delta_m)$$
$$m_{Pb} \rightarrow m_{Pb}(1+\delta_m)$$

$$\text{with } \delta_m = \Delta m / m_{Pb}$$
$$\delta_p = \Delta p / p_{Pb}$$

s[m]	x[mm]	px[1e-3]	y[mm]	py[1e-3]	E[GeV]
356.2727738552087	11.191737909334497	0.4579001842525936	-0.10091572291057689	-0.007773387071119531	532975.1822472928
356.2727738552087	11.496625233901863	0.45983374181958686	-0.6042909435847069	-0.009982089815092493	532987.0469101442
356.2727738552087	11.41993849233247	0.457230674793868	-0.031063363619558606	0.003382804806412896	532908.1996090197
356.2727738552087	11.608769893125471	0.46743617209220867	1.3788814660789375	0.0017811294798974412	532920.1825114983
356.2727738552087	11.18676409431958	0.46096350239369116	-0.4863459247471 6165	0.0005359968490555435	532993.2006033942
356.2727738552087	11.249776295850575	0.46034635348240166	-0.11128541505651827	-0.0012680882112652157	532956.6733004331
356.2727738552087	11.352870008482677	0.452791792102334 5	0.502478064017459	0.002321144421788362	533003.2020621706
356.2727738552087	11.177006668858915	0.4496242989253705	0.08146247536332968	-0.002063345308004155	532965.1632111167
356.2727738552087	11.039842721354015	0.4525273825957543	-0.5770335984120423	-0.013973935653873544	532991.8077566057
356.2727738552087	11.582886857598343	0.4512987588519191	-0.19500767069237815	0.001539105386632527	533026.9930691199

Simulation Scenarios





β = 151m (at collimator front)
$\epsilon_{nominal}$ = 3.5µm/ γ
γ = 6.5TeV/0.938GeV
$\rightarrow \sigma_{nominal} = 133.6\mu m$

How much of the other beams is absorbed if ασ of the BFPP1 beam are intercepted by the collimator jaw?

What effect does the ***length of the collimator*** have on the absorption of the produced shower?

What ***beam properties*** should be used?

Things to be done…

1. Discuss how to proceed with FLUKA runs:
   Initial model of simple jaw

2. Intercept other secondary beams from IP (EMD1, BFPP2, EMD2, …) as function of collimator gap (reduce losses in IR3 and elsewhere).

3. Other positions of the collimator?

4. Check influence of change in sequence on optics
   → include magnet errors?

5. Other optics cases

6. Calculations for B2 on left side of IP2.