Simulation study of pair monitor

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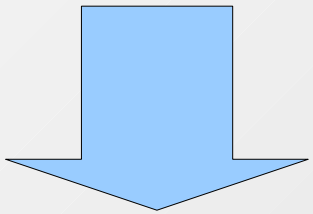
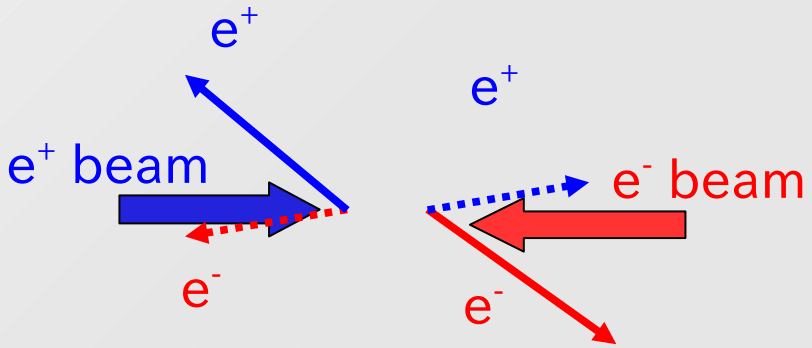
Introduction

- **Pair monitor measures the beam shape at IP, using pair background.**
  - The same charges with respect to the oncoming beam are scattered with large angle.
  - The potential produced by the oncoming beam is a function of beam shape.
  - The scattered particles carry the beam information.
  - Data will be taken for each 164 bunches to get enough statistics.



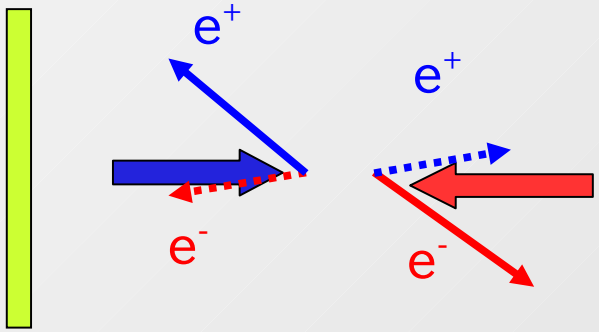


- **Activity of Tohoku group.**
  - Development of the readout ASIC.
  - Simulation study.

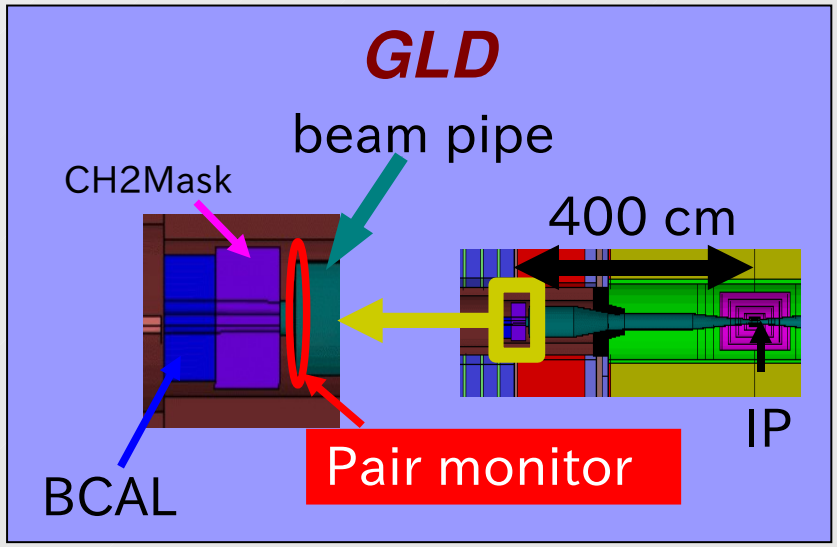
Current status of simulation study is shown.

Simulation setup

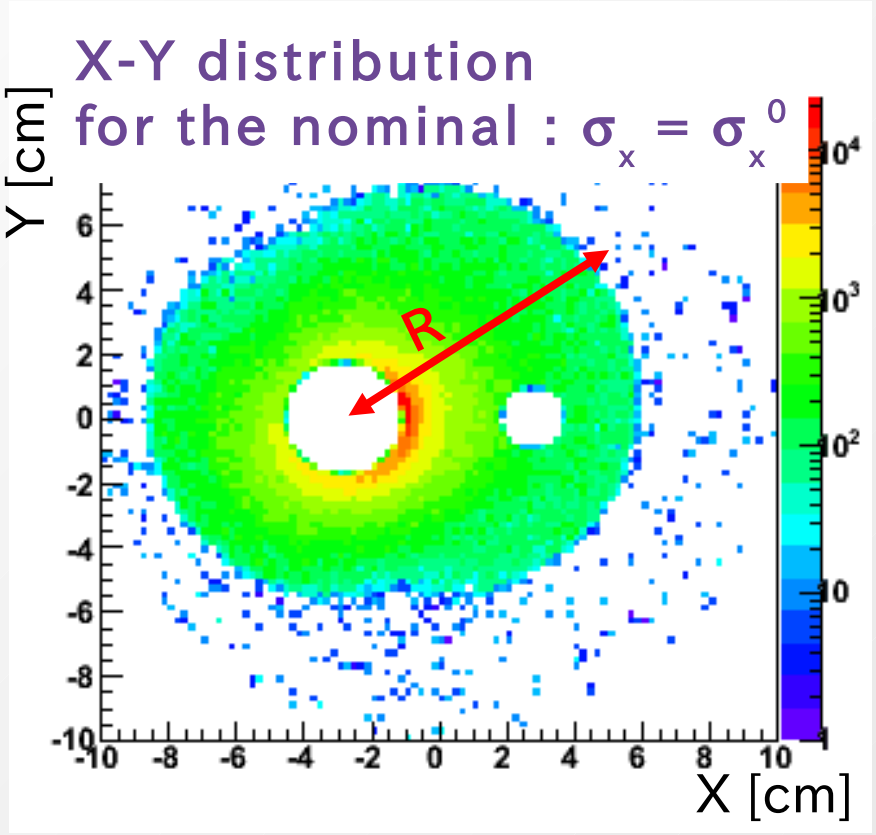
- CM energy : 500 GeV
- Beam size : $(\sigma_x^0, \sigma_y^0, \sigma_z^0) = (639\ \text{nm}, 5.7\ \text{nm}, 300\ \text{mm})$
- Tools : CAIN (e^+e^- generator),
  Jupiter (Tracking emulator)
  - *simulator for GLD.*
- Magnetic field : **3T with anti-DID.**
- Scattered e^+ distribution is studied.

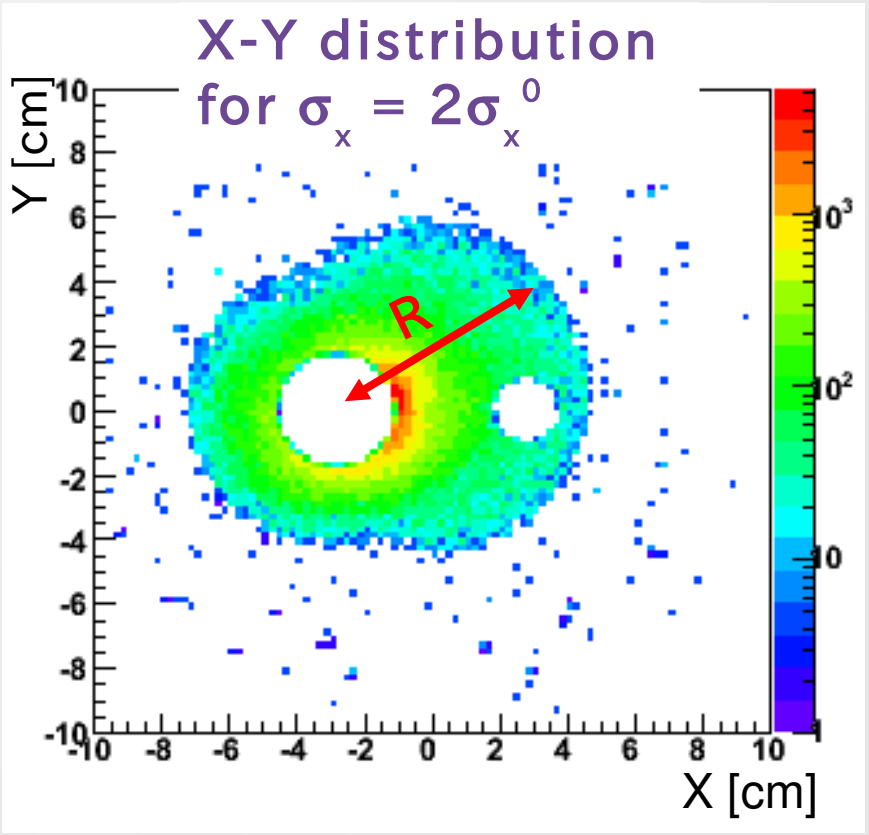


Pair monitor



Measurement of horizontal beam size (σ_x)



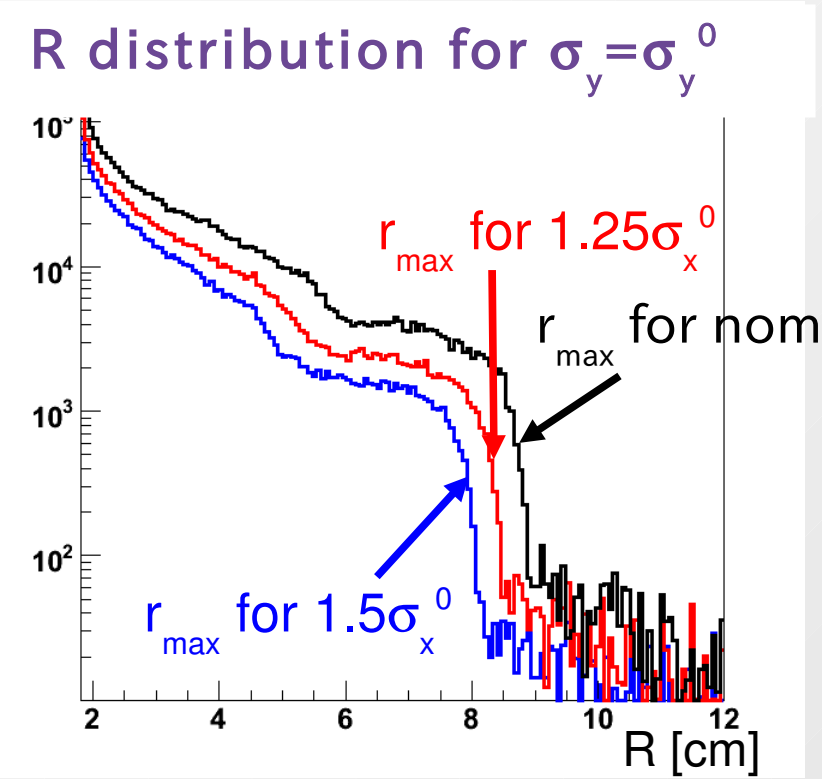


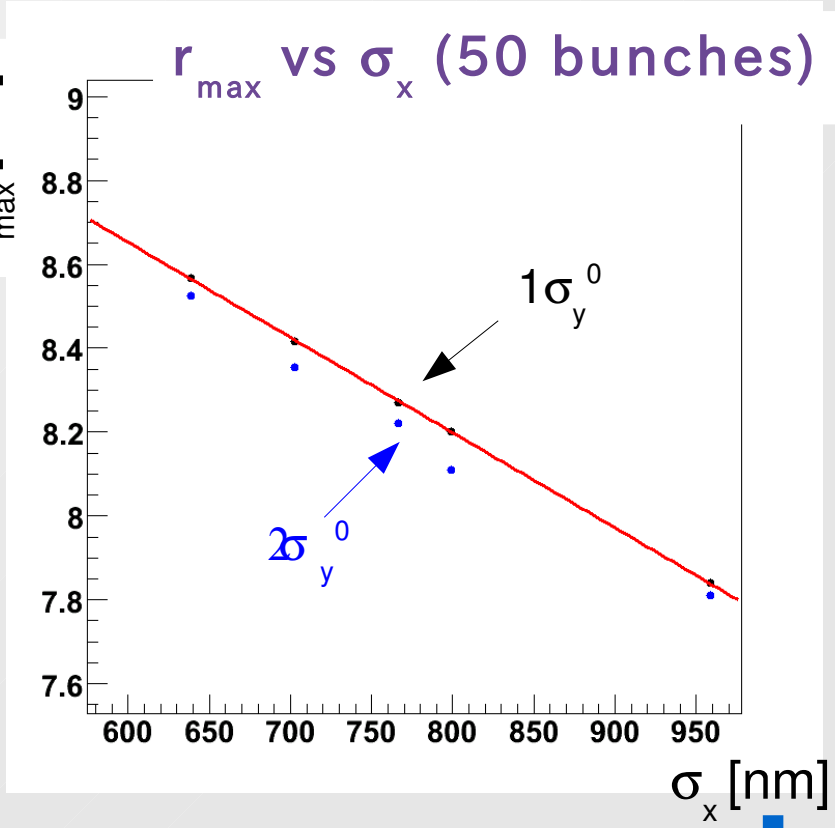
R distribution seems to depend on the horizontal beam size (σ_x).

The maximum R was studied.

Radial distribution and r_{max}

- r_{max} – radius to contain 99.8% of the all hits.



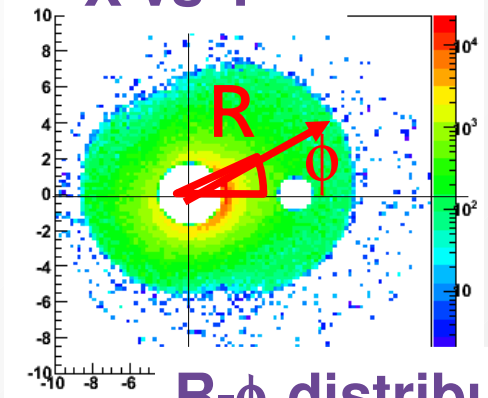


The statistical error is scaled to that of 164 bunches.

Horizontal beam size (σ_x) can be measured by resolution of 0.75 nm for the nominal beam size.

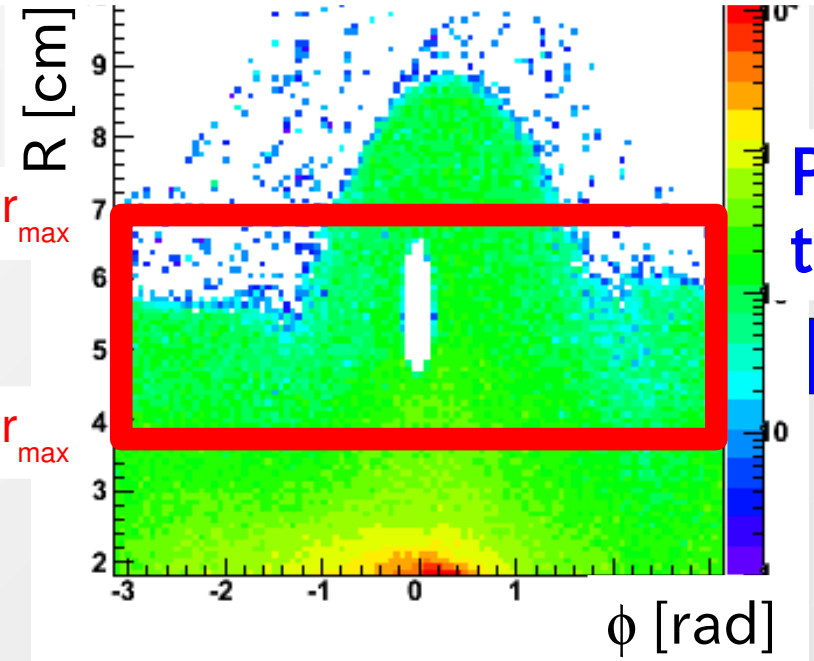
Measurement of vertical beam size (σ_y)

X vs Y



- To derive the beam information, projection to ϕ-axis is checked.

R-ϕ distribution for the nominal



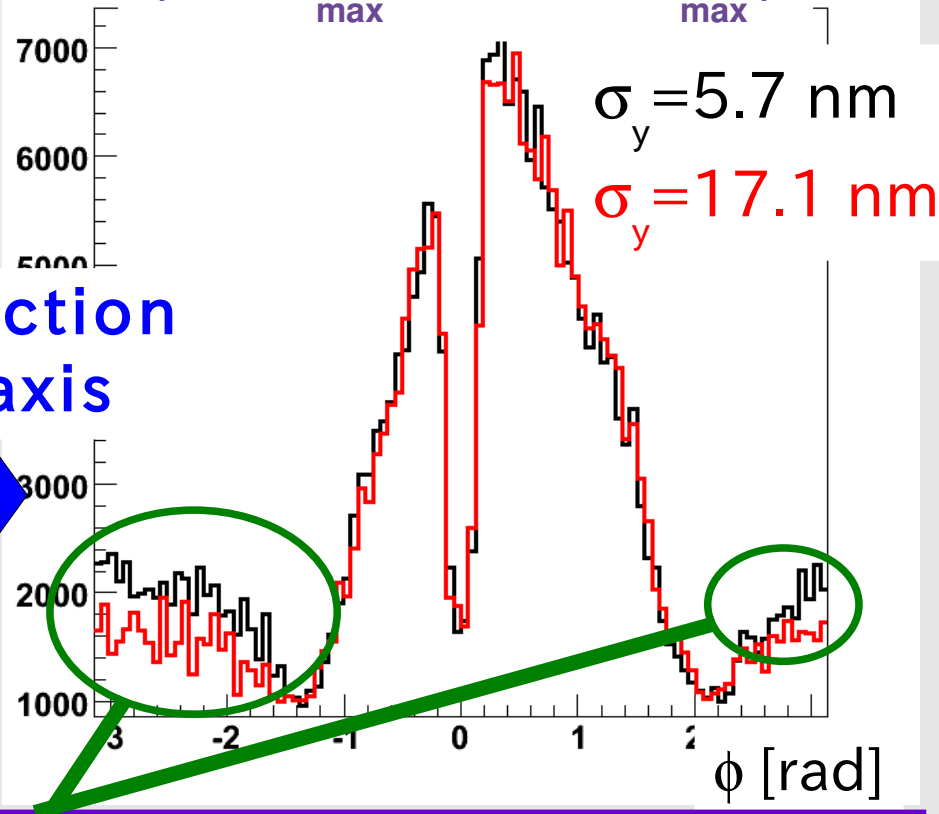
0.8 * r_{max}

0.5 * r_{max}

Projection to ϕ-axis

ϕ distribution

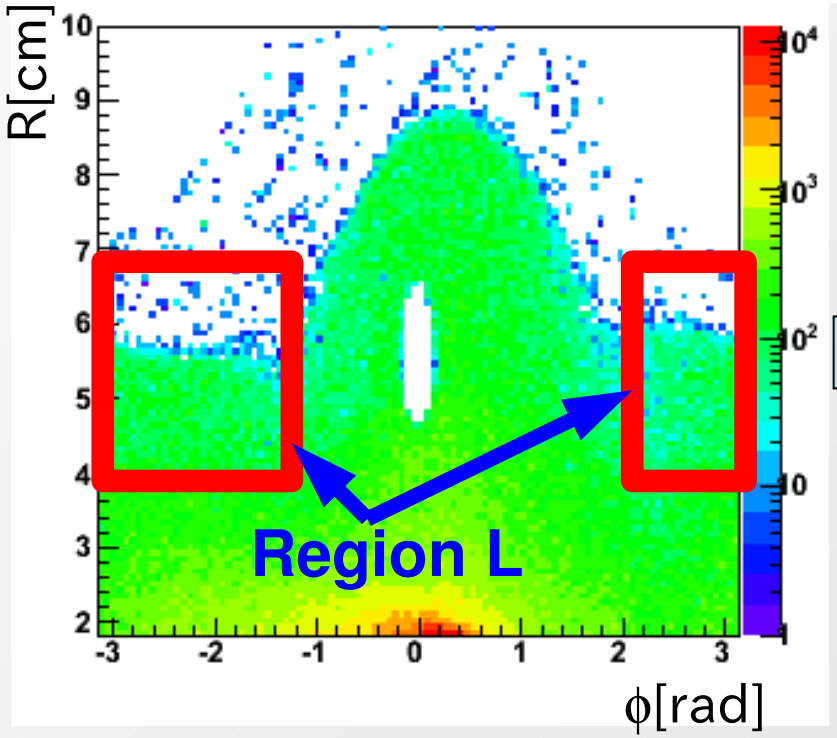
(0.5*r_{max} < R < 0.8*r_{max})



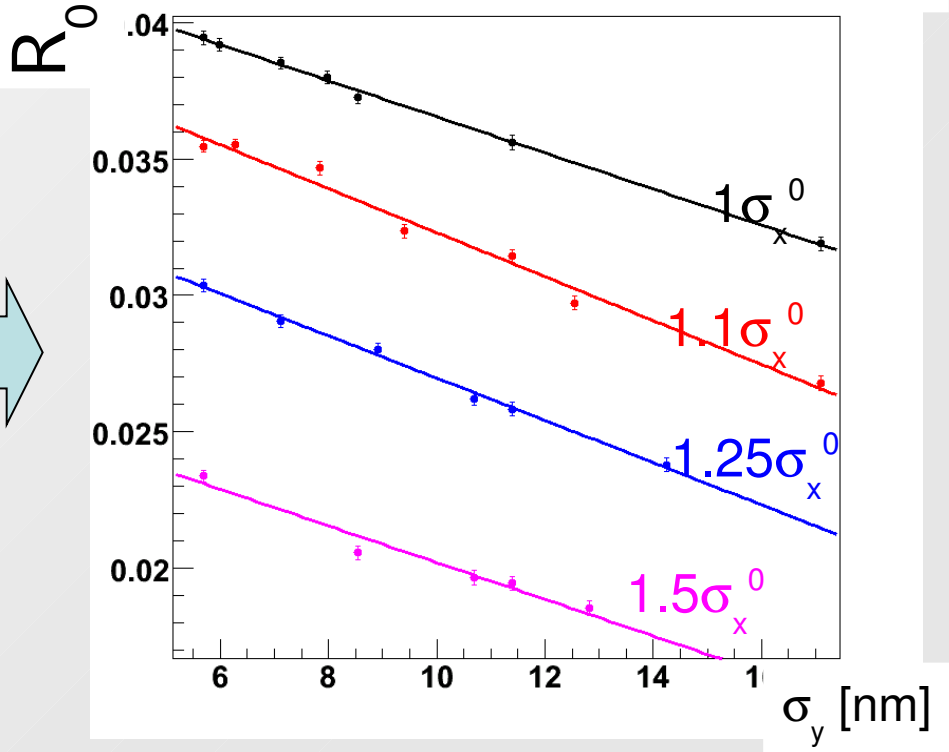
There is the information of σ_y in this region.

Resolution of vertical beam size (σ_y)

R-ϕ distribution for the nominal



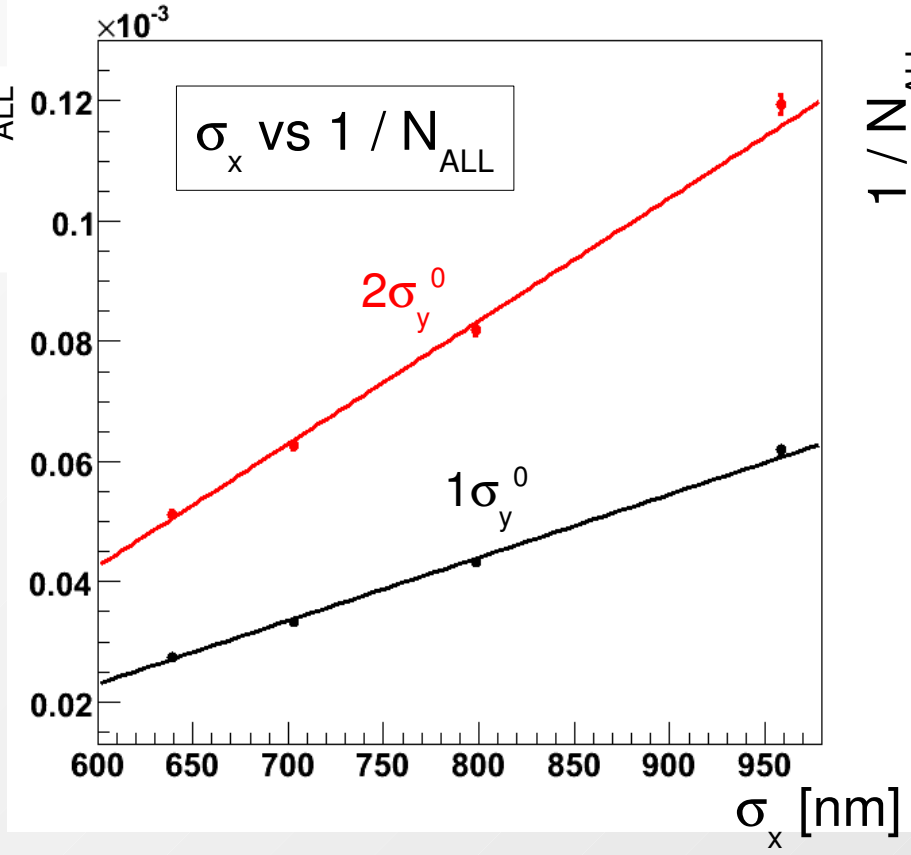
$R_0 = N_L/N_{ALL}$ (50 bunches)

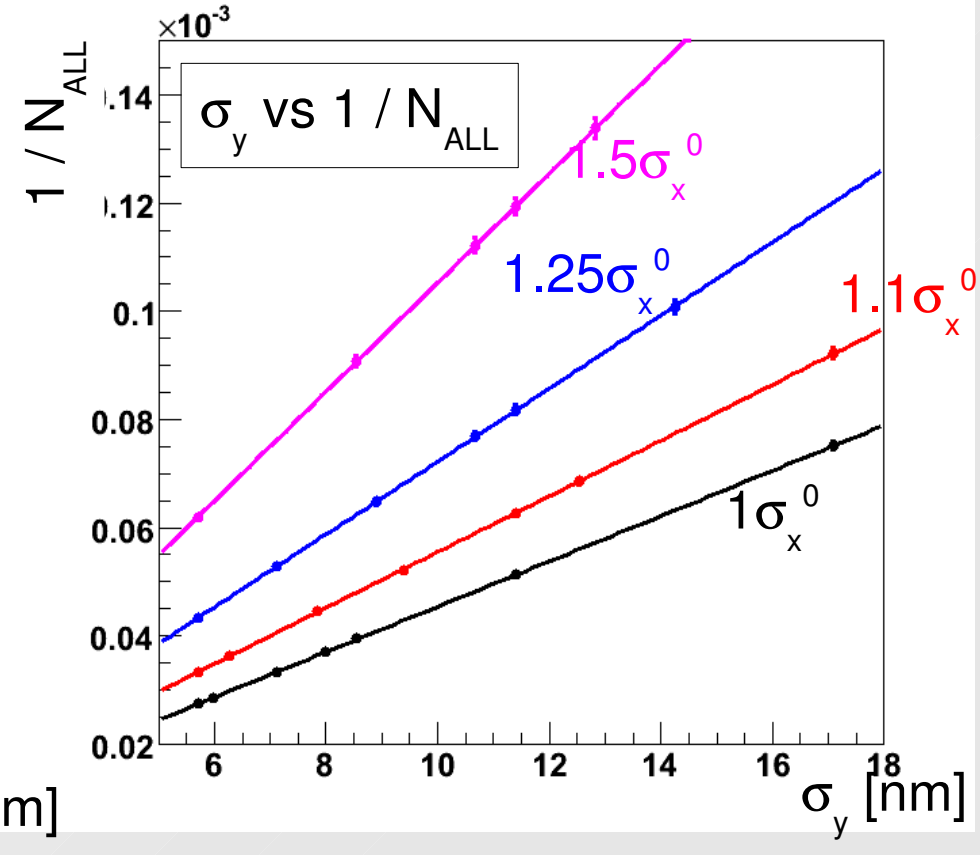


The statistical error is scaled to that of 164 bunches.
Vertical beam size (σ_y) can be measured by resolution of 0.20 nm (3.5%) for the nominal beam size.

The number of all hits per bunch (N_{ALL})

- The number of hits also have information of beam shape.





$1/N_{ALL}$ has linear dependence on beam size (σ_x, σ_y).

Is it possible to measure σ_x and σ_y with r_{max}, R_0 and $1/N_{ALL}$?

Measurement of vertical and horizontal beam size (σ_y, σ_x)

$$\begin{cases} r_{max}(\sigma_x,\sigma_y) = r_{max}(\sigma_x^0,\sigma_y^0) + \dfrac{\partial r_{max}}{\partial \sigma_x}(\sigma_x-\sigma_x^0) + \dfrac{\partial r_{max}}{\partial \sigma_y}(\sigma_y-\sigma_y^0) + \cdots \\ R_0(\sigma_x,\sigma_y) = R_0(\sigma_x^0,\sigma_y^0) + \dfrac{\partial R_0}{\partial \sigma_x}(\sigma_x-\sigma_x^0) + \dfrac{\partial R_0}{\partial \sigma_y}(\sigma_y-\sigma_y^0) + \cdots \\ \dfrac{1}{N_{ALL}}(\sigma_x,\sigma_y) = \dfrac{1}{N_{ALL}}(\sigma_x^0,\sigma_y^0) + \dfrac{\partial}{\partial \sigma_x}\left(\dfrac{1}{N_{ALL}}\right)(\sigma_x-\sigma_x^0) + \dfrac{\partial}{\partial \sigma_y}\left(\dfrac{1}{N_{ALL}}\right)(\sigma_y-\sigma_y^0) + \cdots \end{cases}$$

$$\begin{pmatrix} \alpha\times(r_{max}-r_{max}^0) \\ \beta\times(R_0-R_0^0) \\ \chi\times(\dfrac{1}{N_{ALL}}-\dfrac{1}{N_{ALL}^0}) \end{pmatrix} = \begin{pmatrix} \alpha\times\dfrac{\partial r_{max}}{\partial \sigma_x} & \alpha\times\dfrac{\partial r_{max}}{\partial \sigma_y} \\ \beta\times\dfrac{\partial R_0}{\partial \sigma_x} & \beta\times\dfrac{\partial R_0}{\partial \sigma_y} \\ \chi\times\dfrac{\partial}{\partial \sigma_x}\left(\dfrac{1}{N_{ALL}}\right) & \chi\times\dfrac{\partial}{\partial \sigma_y}\left(\dfrac{1}{N_{ALL}}\right) \end{pmatrix} \begin{pmatrix} \sigma_x-\sigma_x^0 \\ \sigma_y-\sigma_y^0 \end{pmatrix}$$

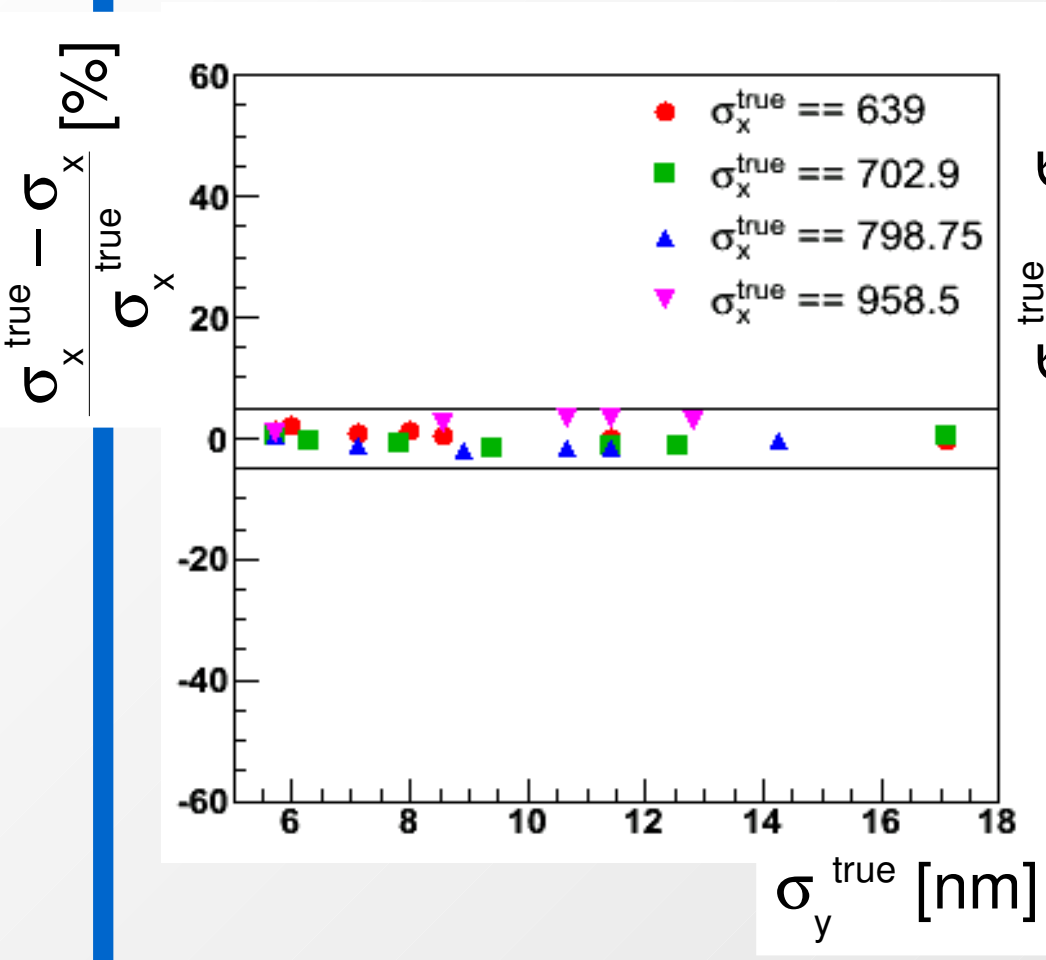
α, β, χ are weights.

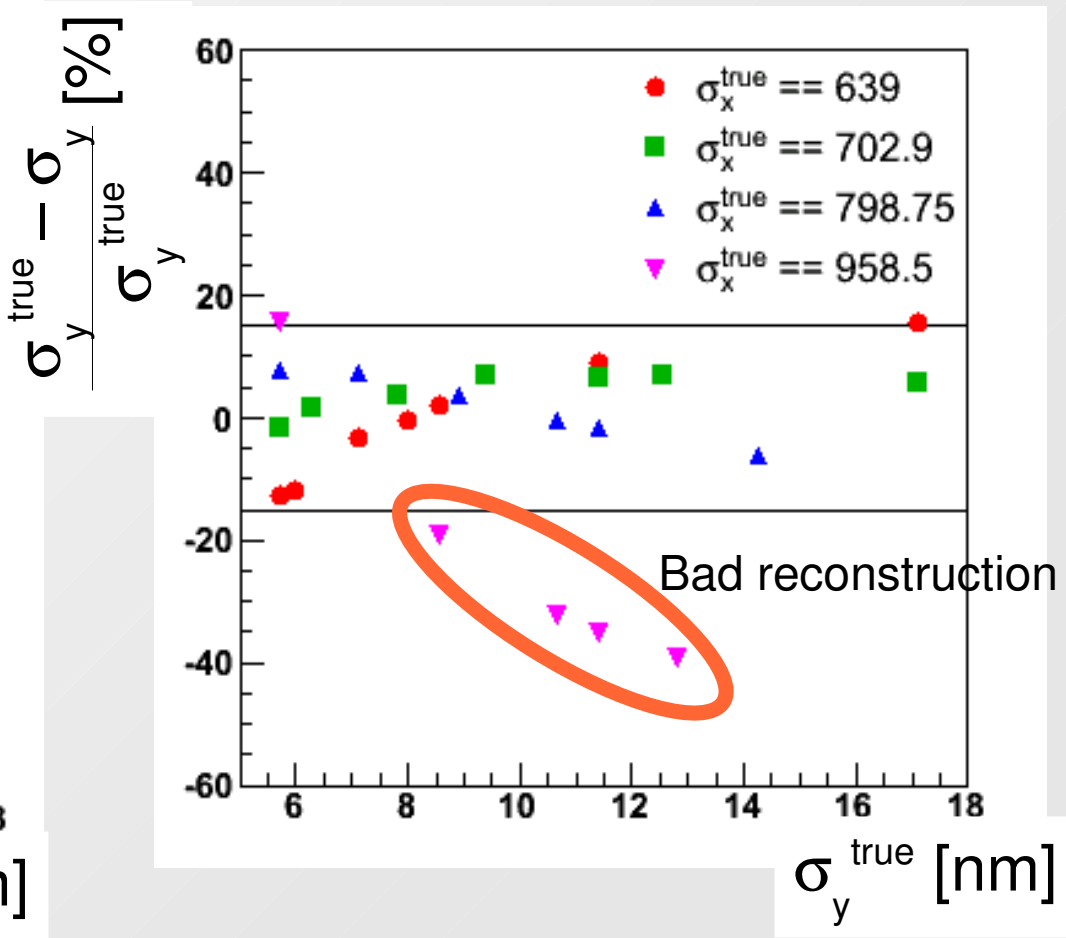
$$\downarrow$$

$$m = Ax$$

$$(A^T A)^{-1} A^T m = x = \begin{pmatrix} \sigma_x-\sigma_x^0 \\ \sigma_y-\sigma_y^0 \end{pmatrix}$$

Results



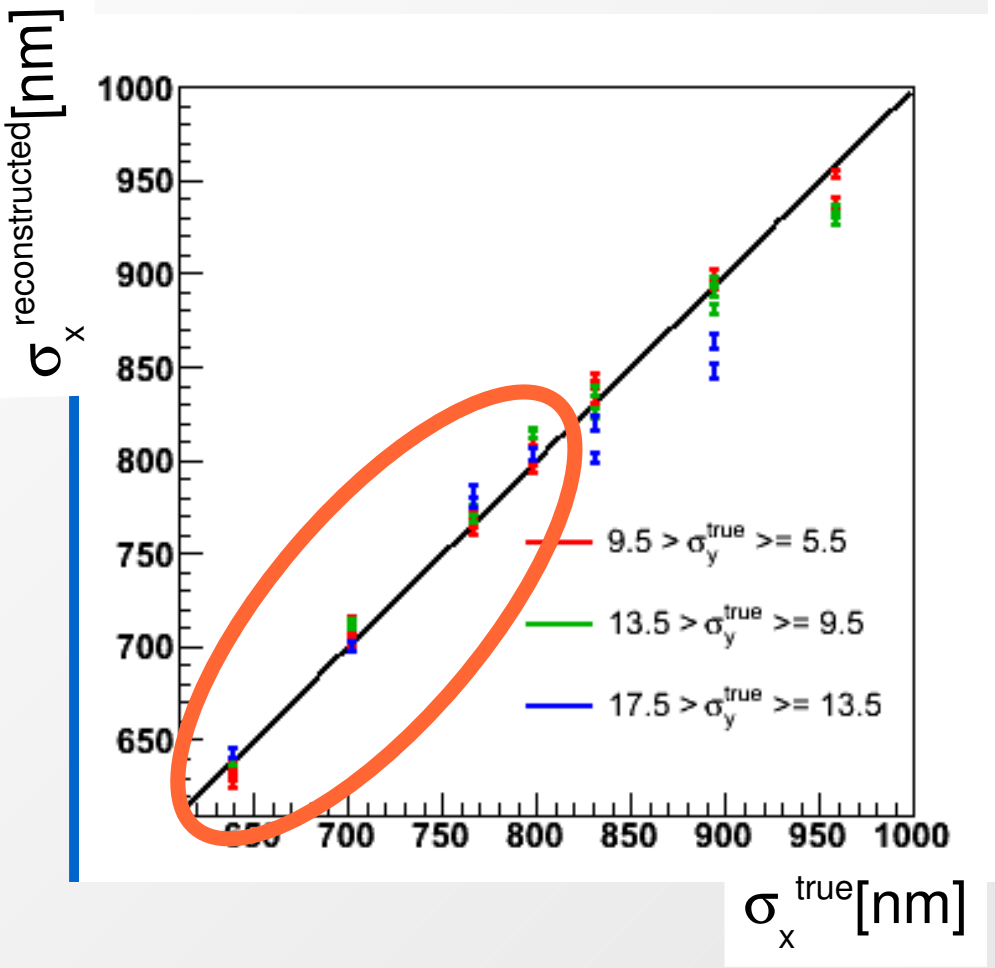


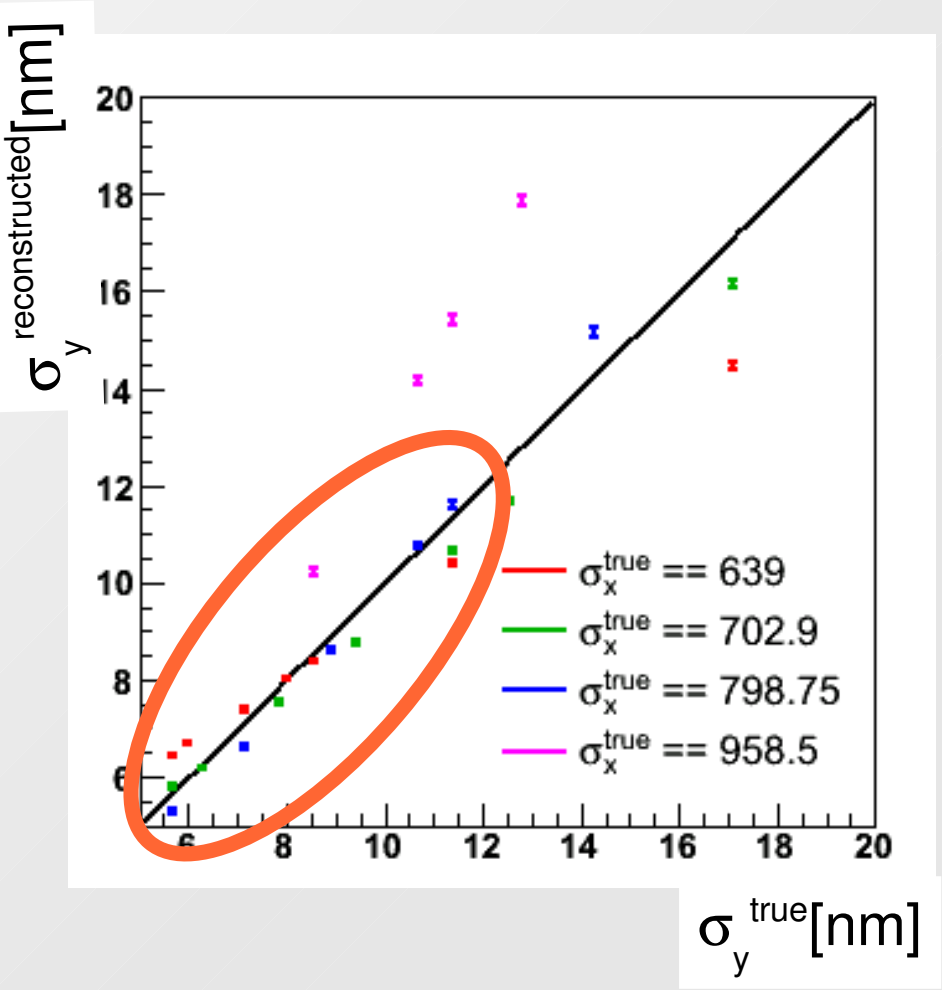
σ_x can be measure with 5%.

σ_y can be measure with 15%.

Measurement of σ_y should be improved to 10% accuracy.

True value vs reconstructed value





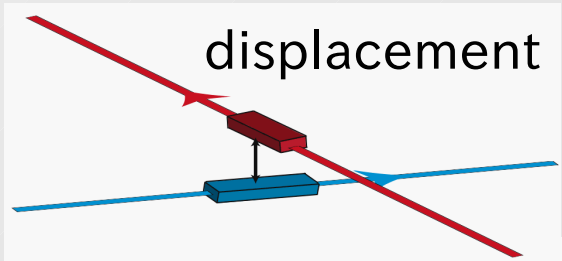
The matrix method works for around the nominal beam size.

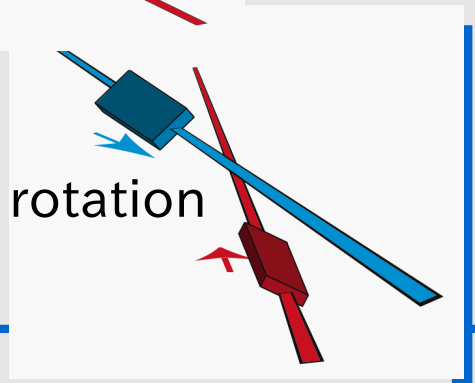
Conclusions

- Pair monitor measures the beam shape at IP.
- Single measurement
  - Vertical beam size (σ_y) can be measured by 0.20 nm for the standard beam.
  - Horizontal beam size (σ_x) can be measured by 0.75 nm for the standard beam.
- Double measurement(σ_x and σ_y) is started with matrix.

Plans

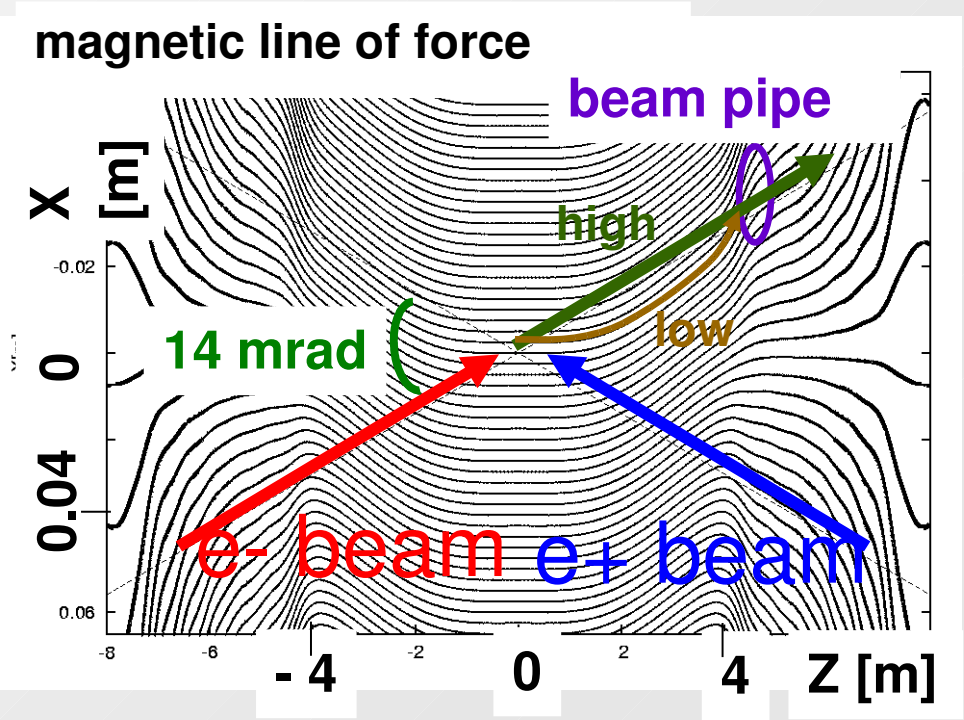
- Measurement of more beam information.
  - displacement, rotation, …
- Simulation study with more accurate magnetic field.
  - 3-D magnetic field map of GLD will be prepared.

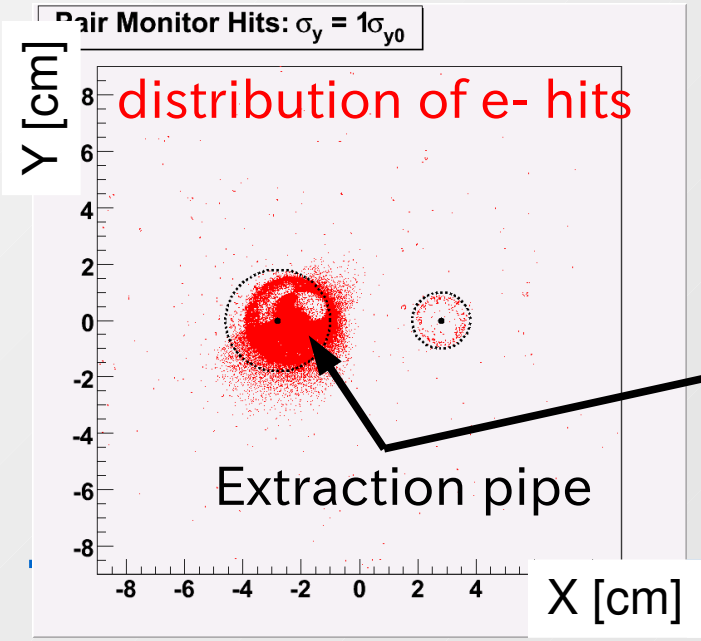


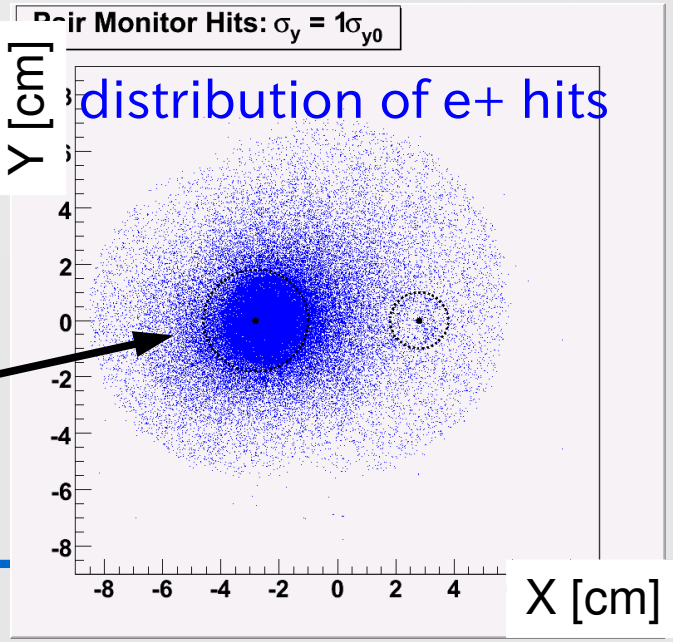


anti-DID field

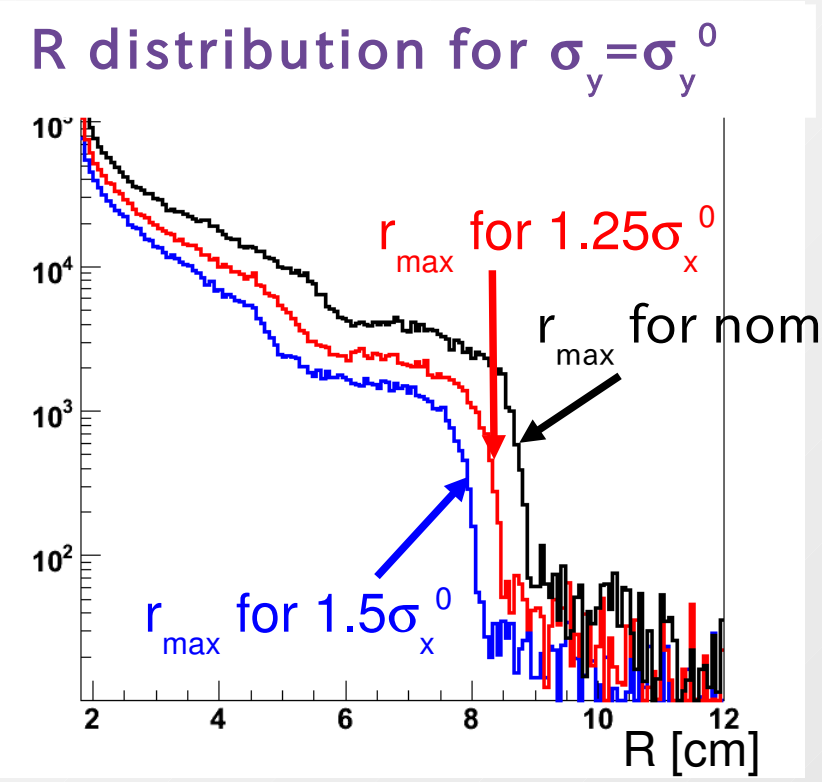
- anti-DID is the magnetic field to lead the pair backgrounds to the beam pipe.
- anti-DID field of the first order of approximation was used.

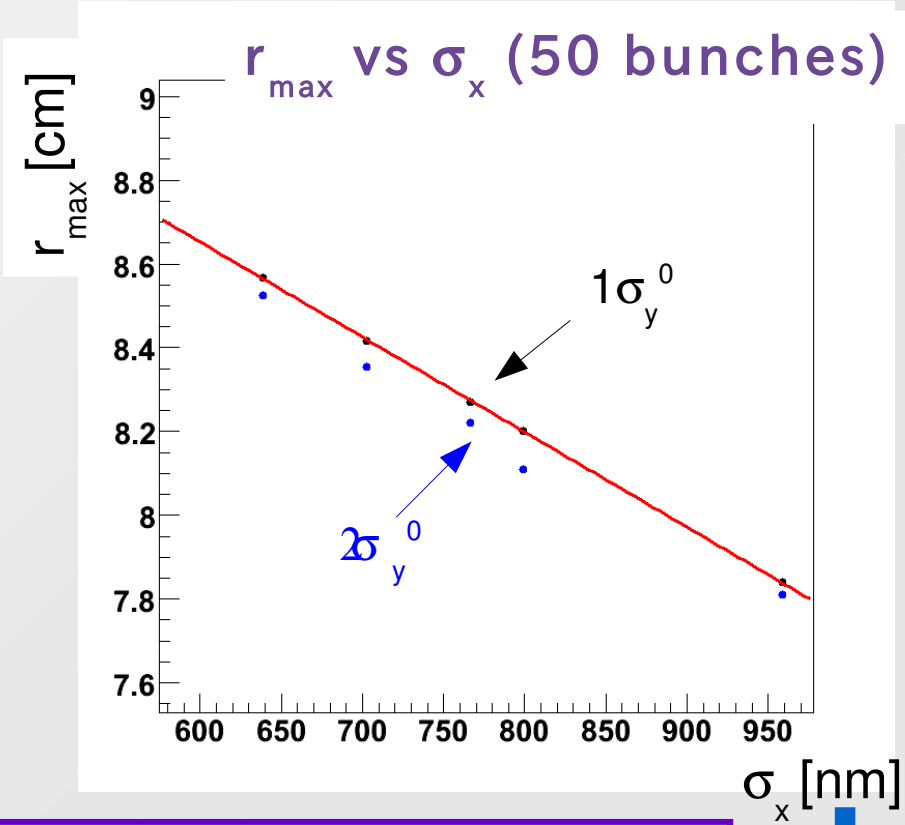






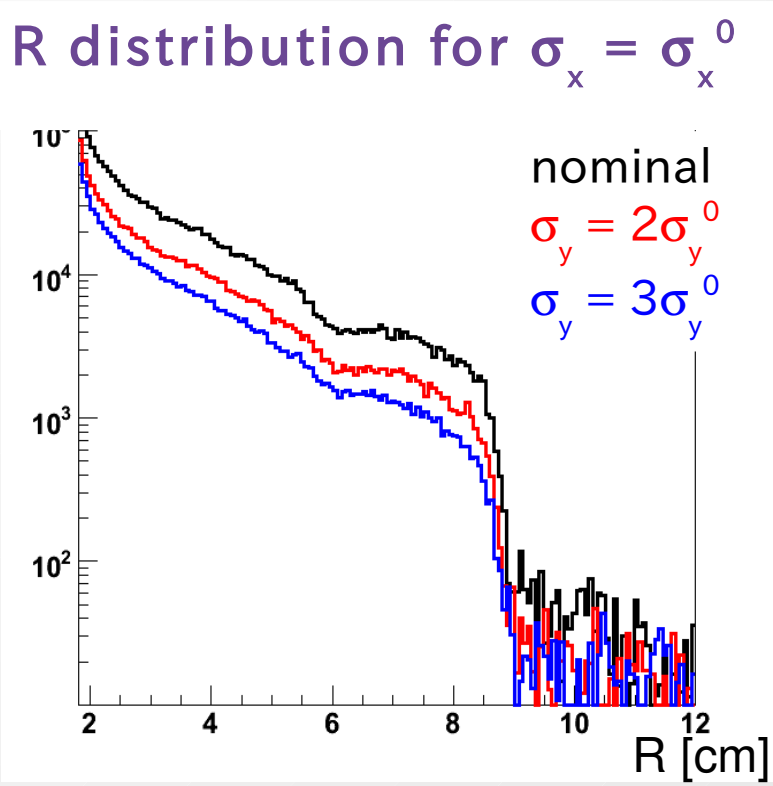
Radial distribution

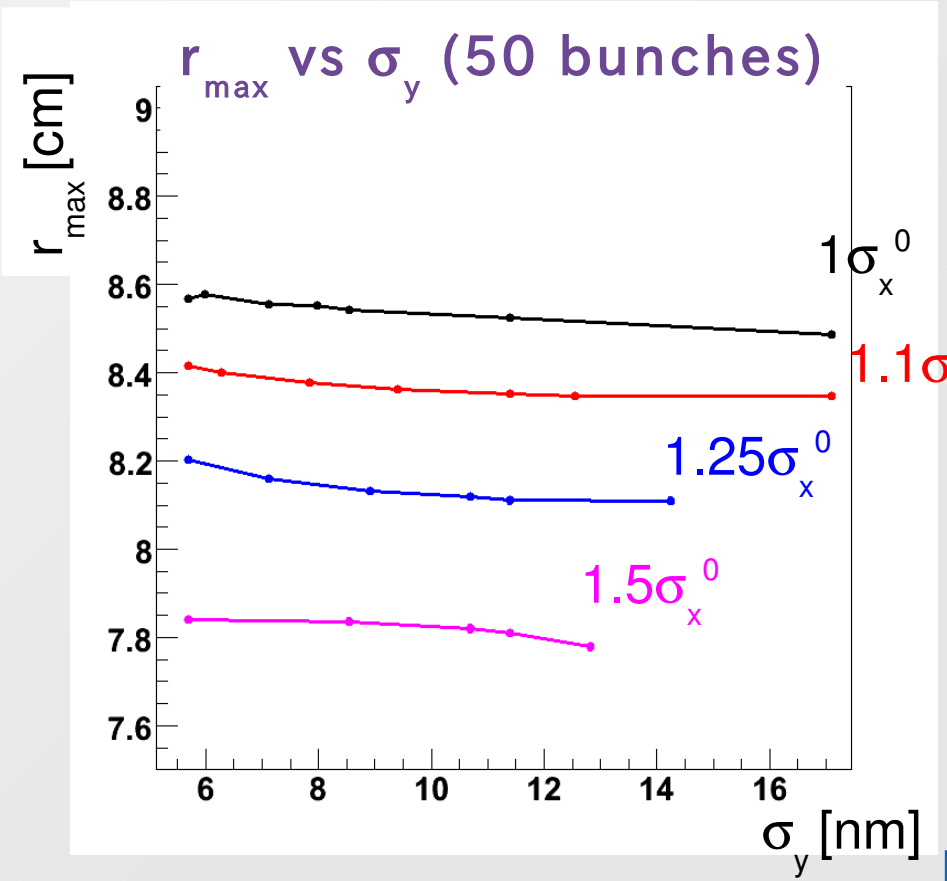




r_{max} depend on horizontal beam size (σ_x).

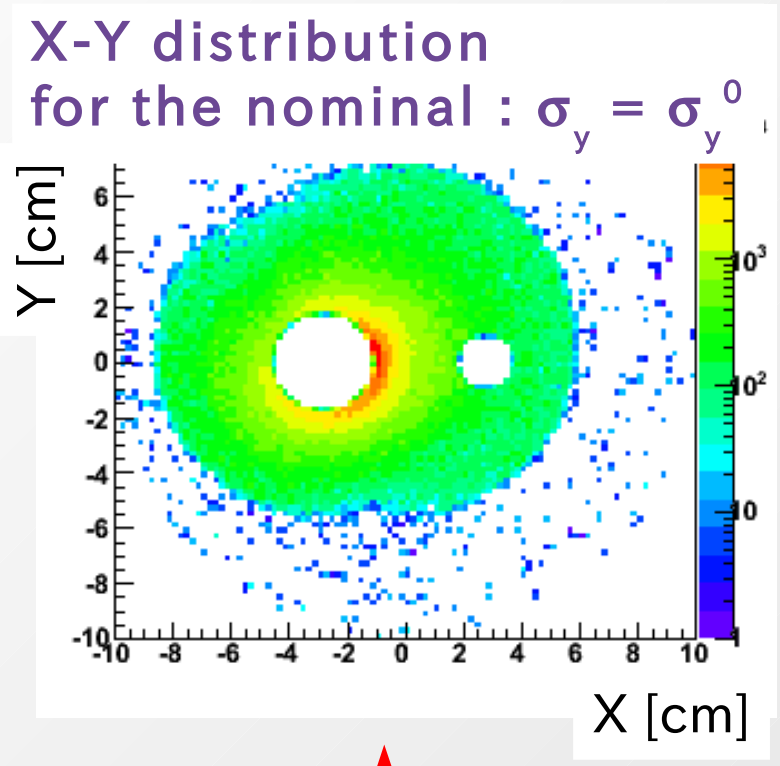
Radial distribution

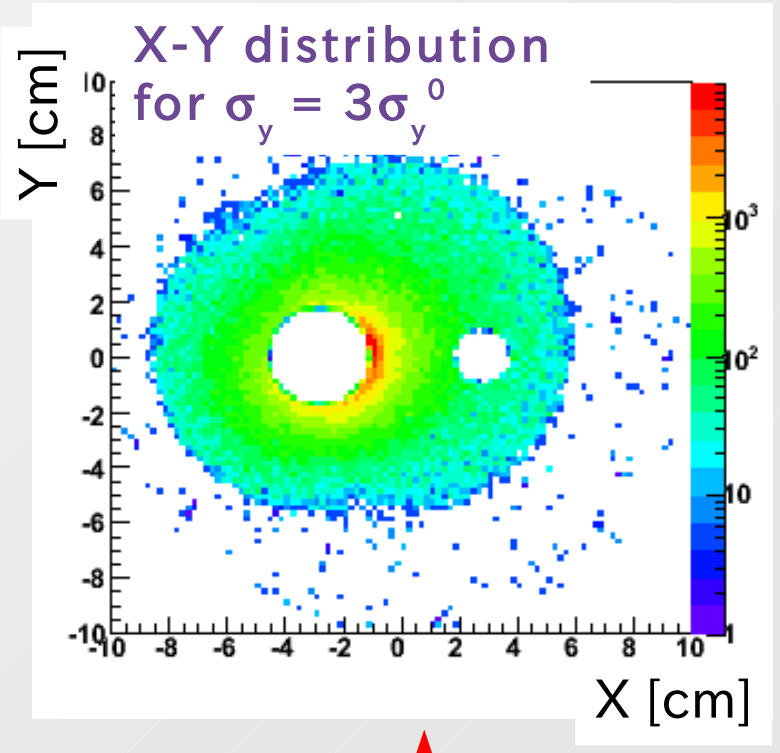


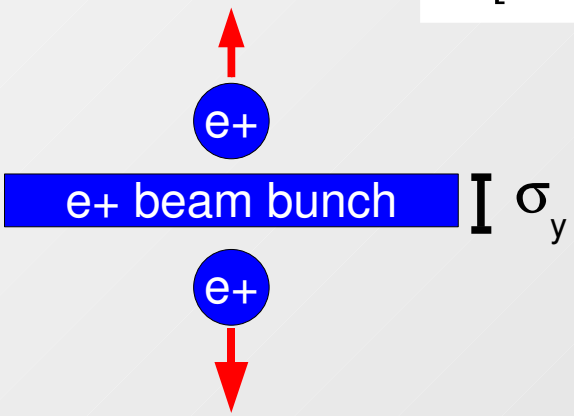


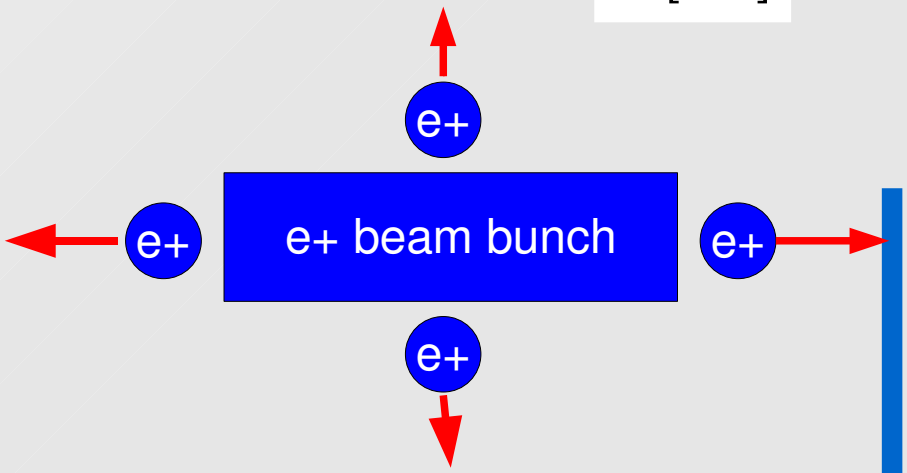
r_{max} does not depend on vertical beam size (σ_y).

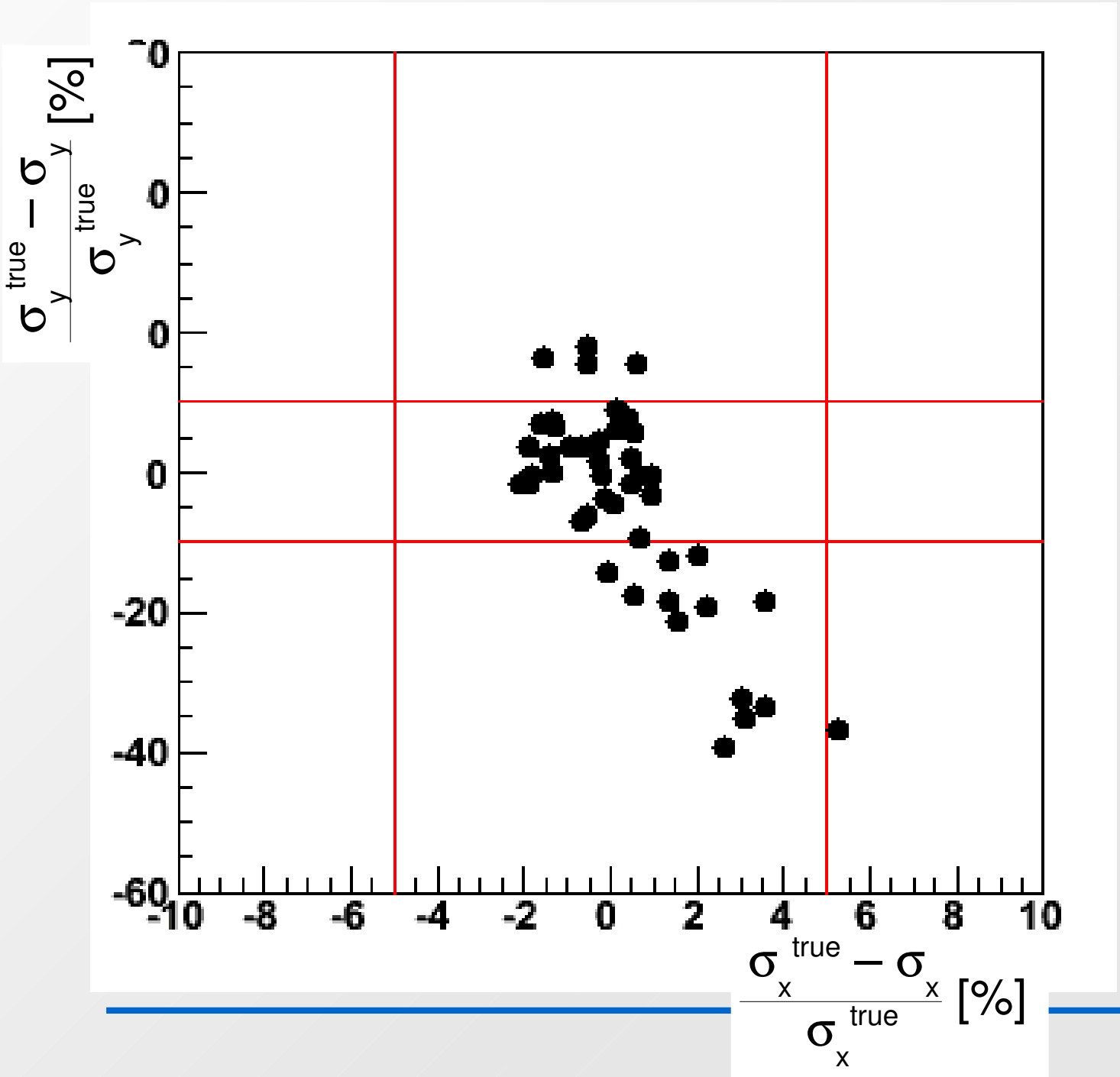
The Hit distribution changes with σ_y










$\frac{\sigma_y^{true} - \sigma_y}{\sigma_y^{true}}$ [%]
0
0
0
-20
-40
-60
-10
-8
-6
-4
-2
0
2
4
6
8
10
$\frac{\sigma_x^{true} - \sigma_x}{\sigma_x^{true}}$ [%]