Simulation study of pair monitor

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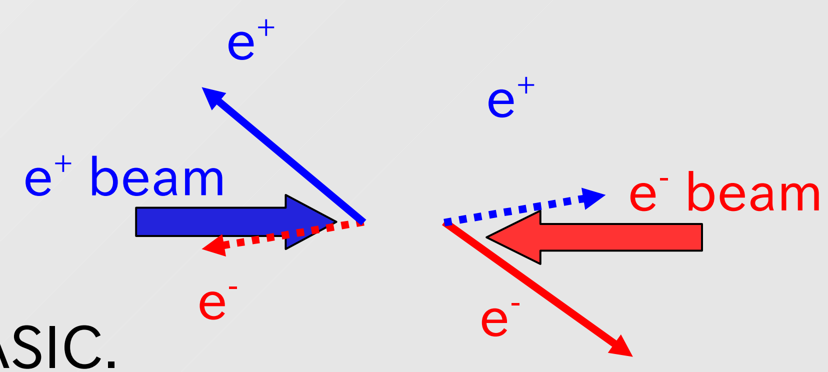
11 Jan 2008

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.
  - The pair monitor is the silicon pixel sensor to detect the pair background.
  - Data will be taken for each 164 bunches to get enough statistics.

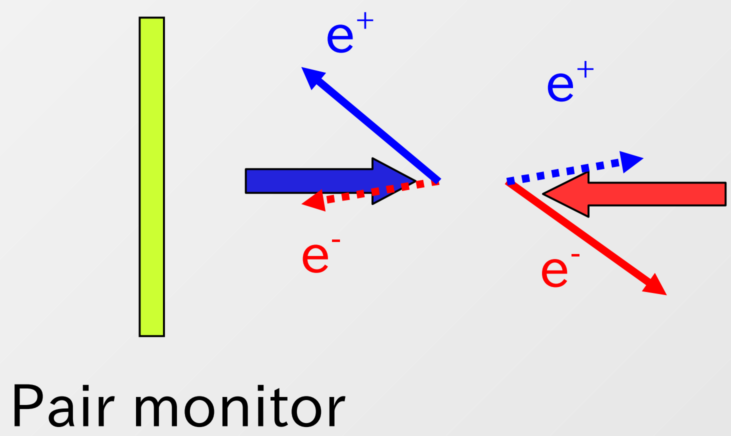


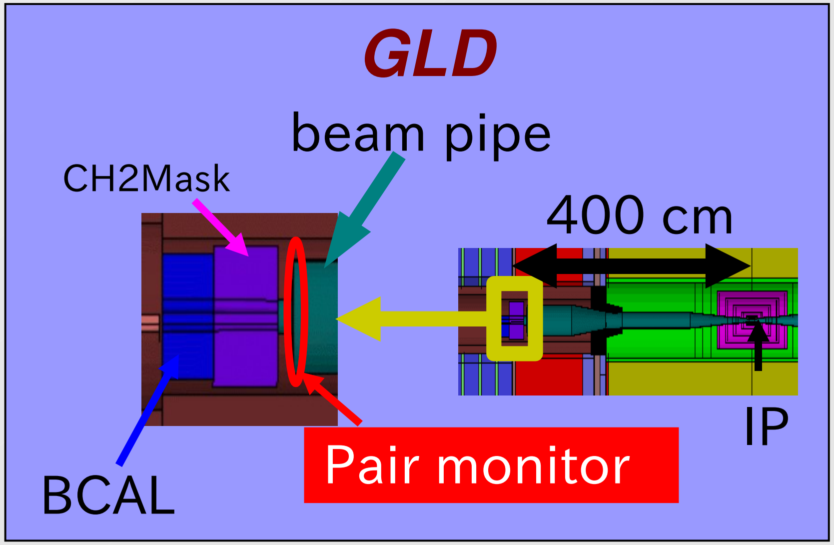
- **Activity of Tohoku group.**
  - Development of the readout ASIC.
  - Simulation study.

Current status of simulation study is shown.

Simulation setup

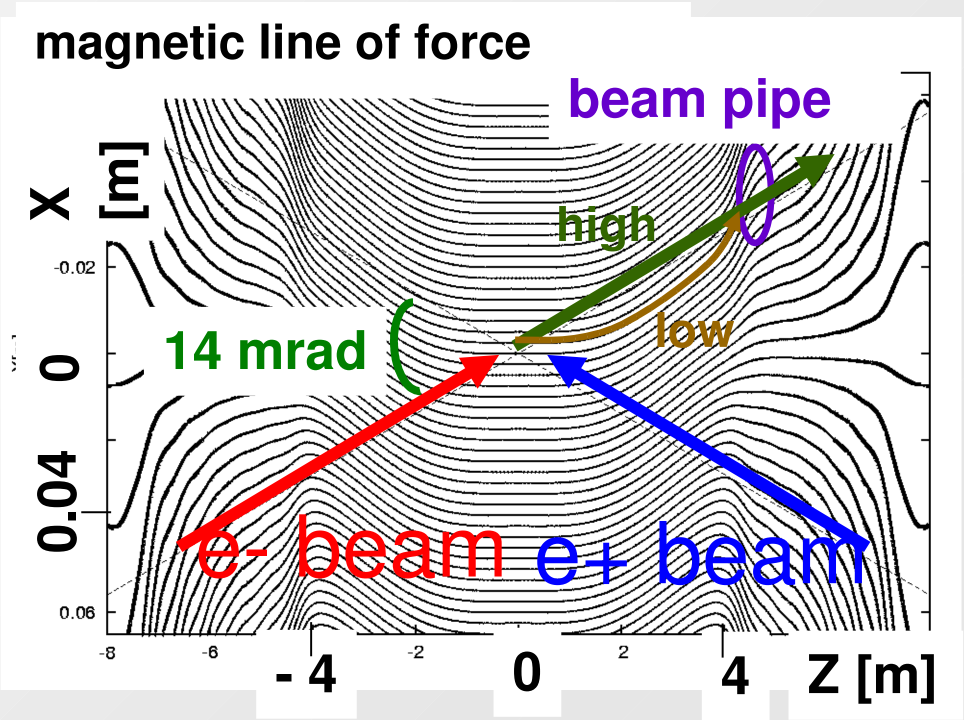
- CM energy : 500 GeV
- Beam size : $(\sigma_x^0, \sigma_y^0, \sigma_z^0)$ = (639 nm, 5.7 nm, 300 mm)
- Tools : CAIN (e^+e^- generator),
  Jupiter (Tracking emulator)
    - *simulator for GLD.*
- Magnetic field : **3T with anti-DID.**
- Scattered e^+ distribution is studied.

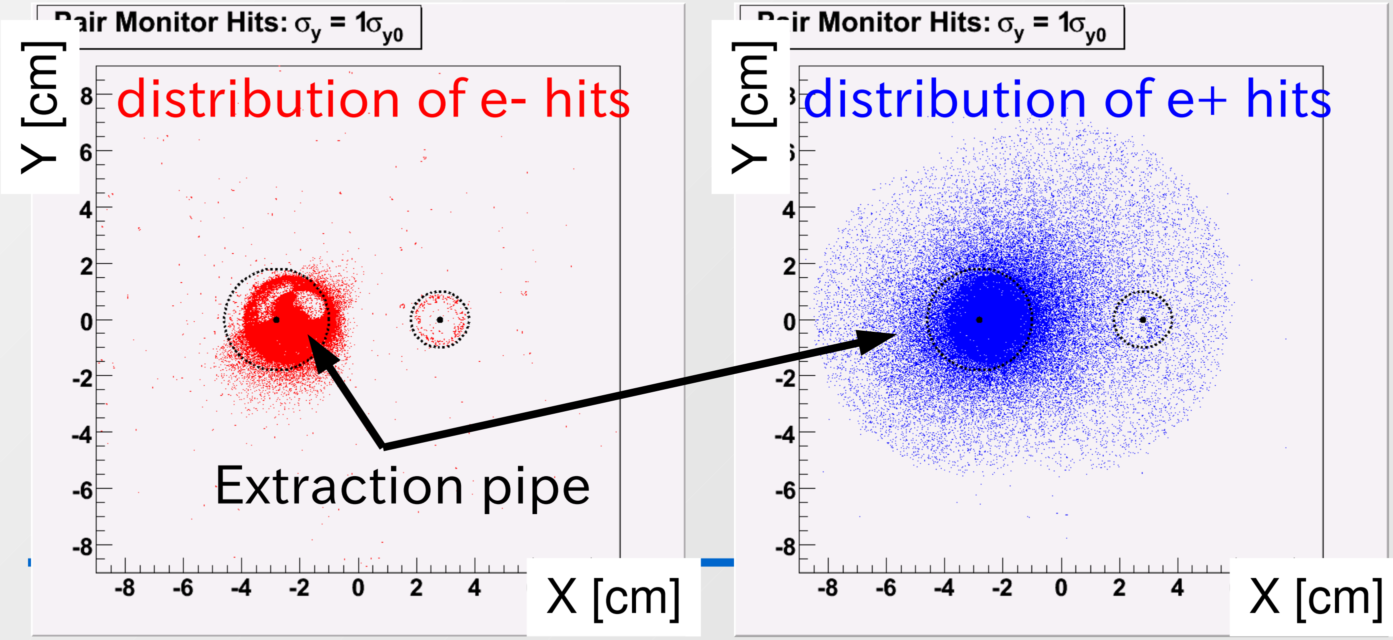




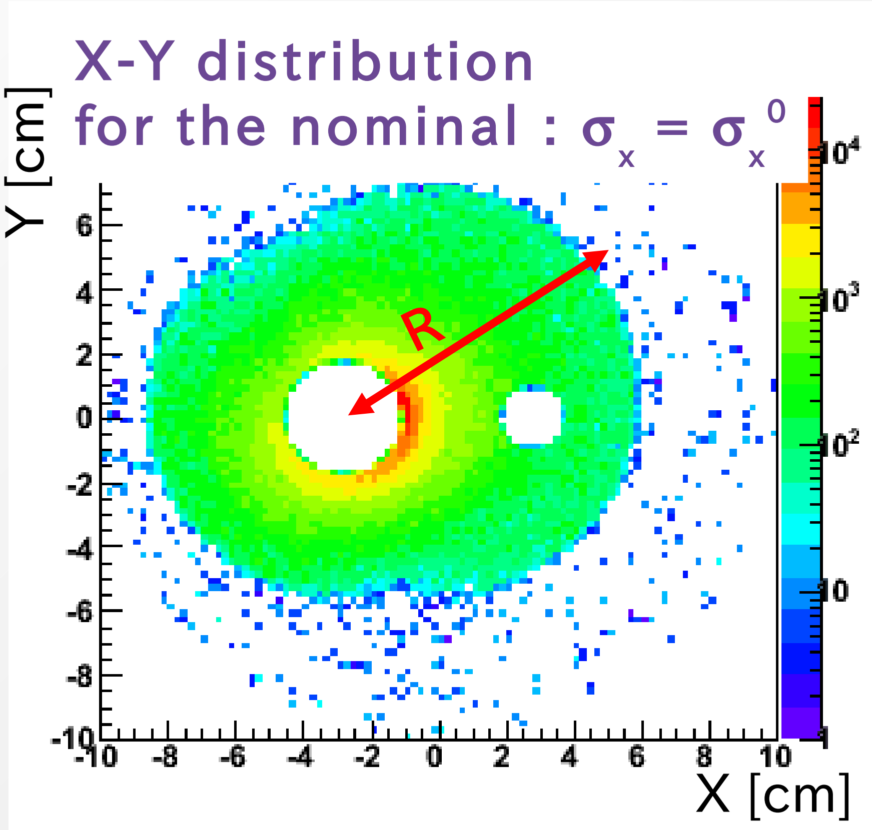
anti-DID field

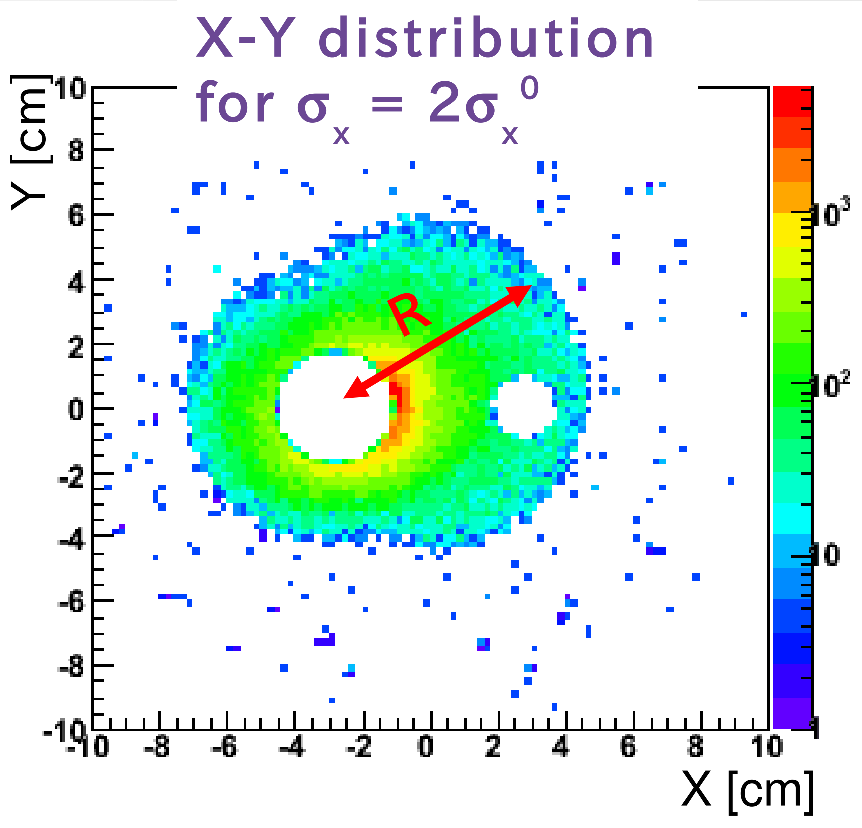
- anti-DID is the magnetic field to lead the pair backgrounds to the beam pipe.
- anti-DID field of the first order of approximation was used.
- The preparation of 3-D field map is ongoing.





Measurement of horizontal beam size (σ_x)





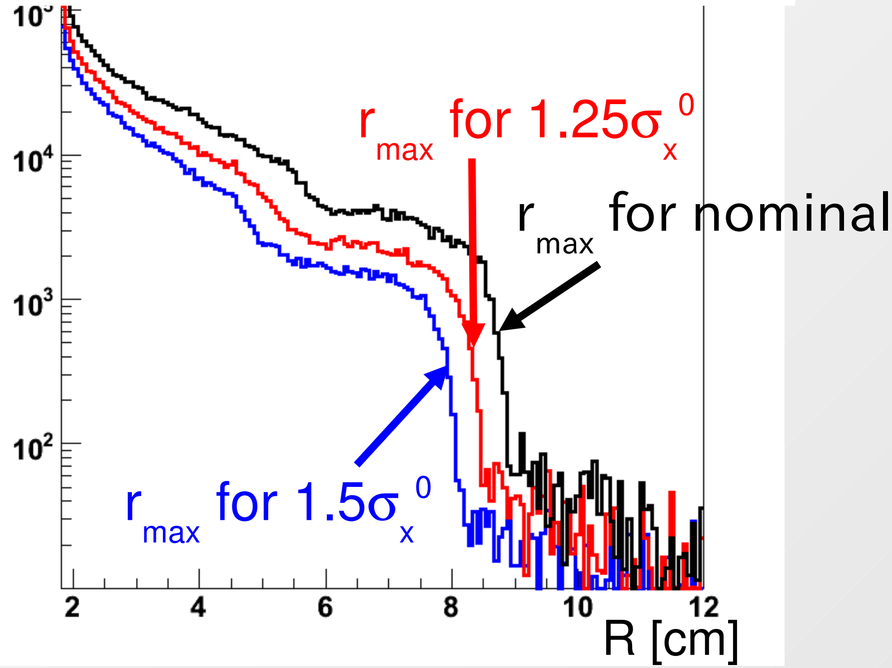
R distribution seems to depend on the horizontal beam size (σ_x).

The maximum R was studied.

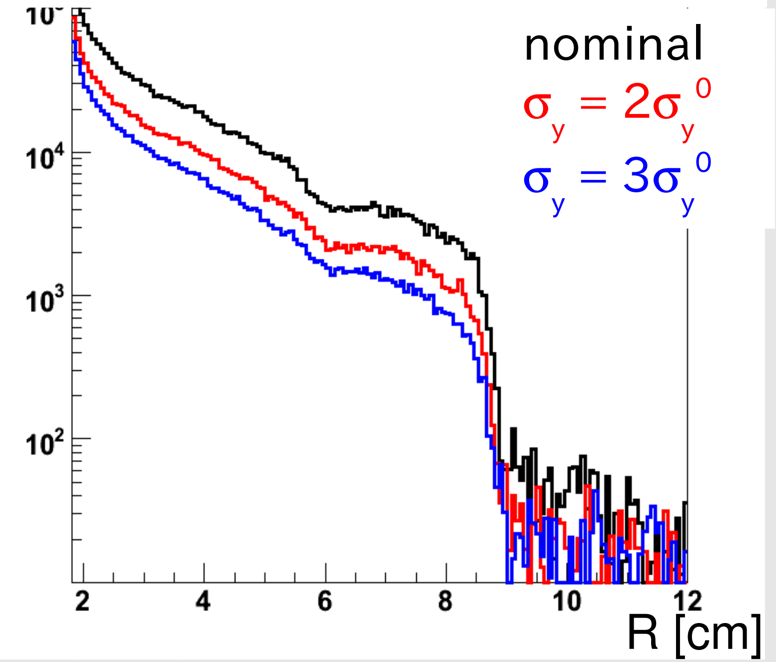
Radial distribution and r_{max}

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

R distribution for $\sigma_y = \sigma_y^0$



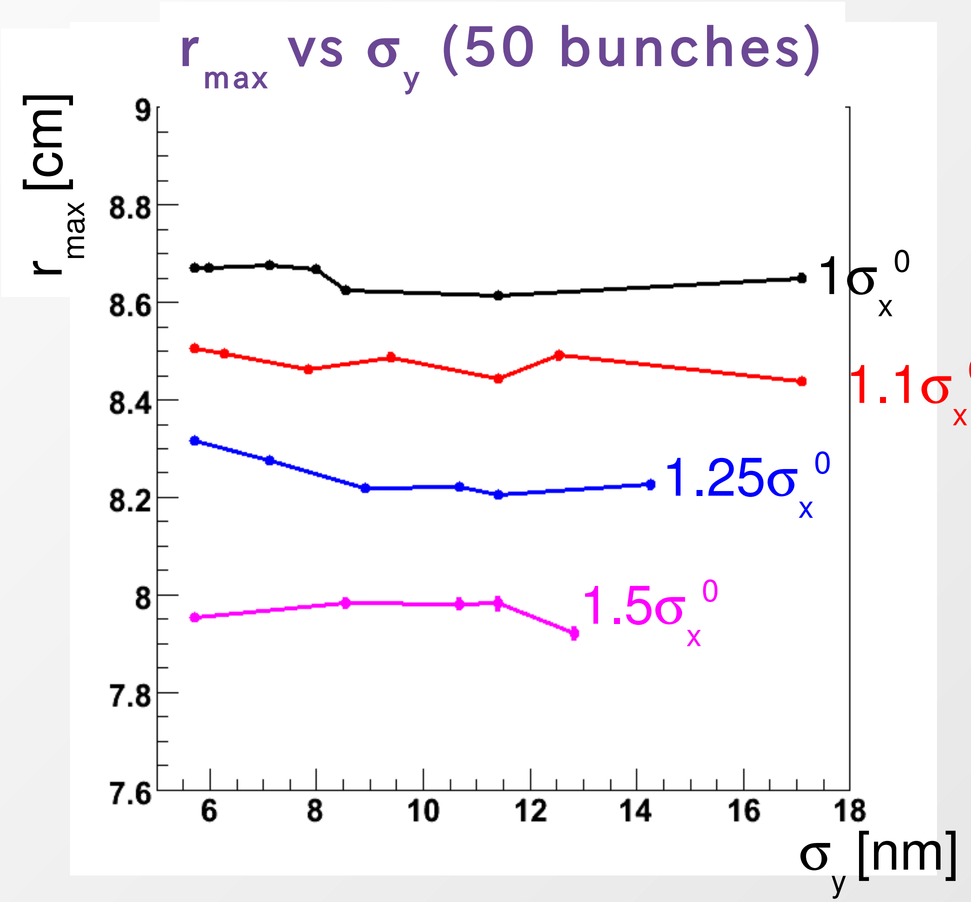
R distribution for $\sigma_x = \sigma_x^0$

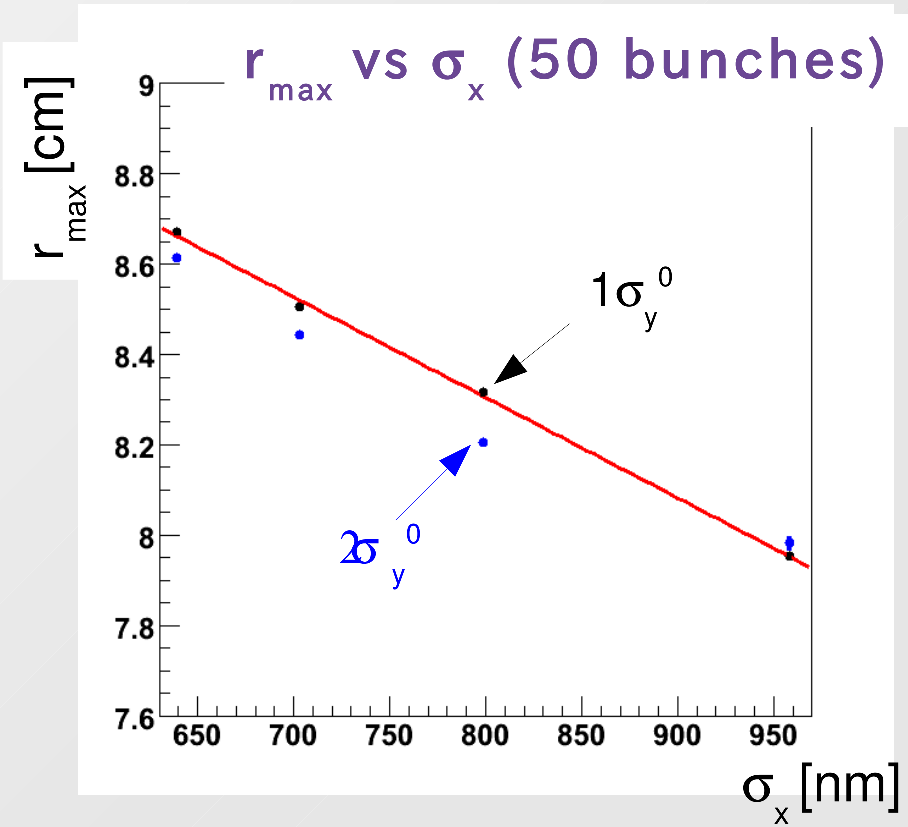


r_{max} depend on horizontal beam size (σ_x) and does not depend on vertical beam size (σ_y).

r_{max} can measure vertical beam size (σ_x).

measurement accuracy of σ_x

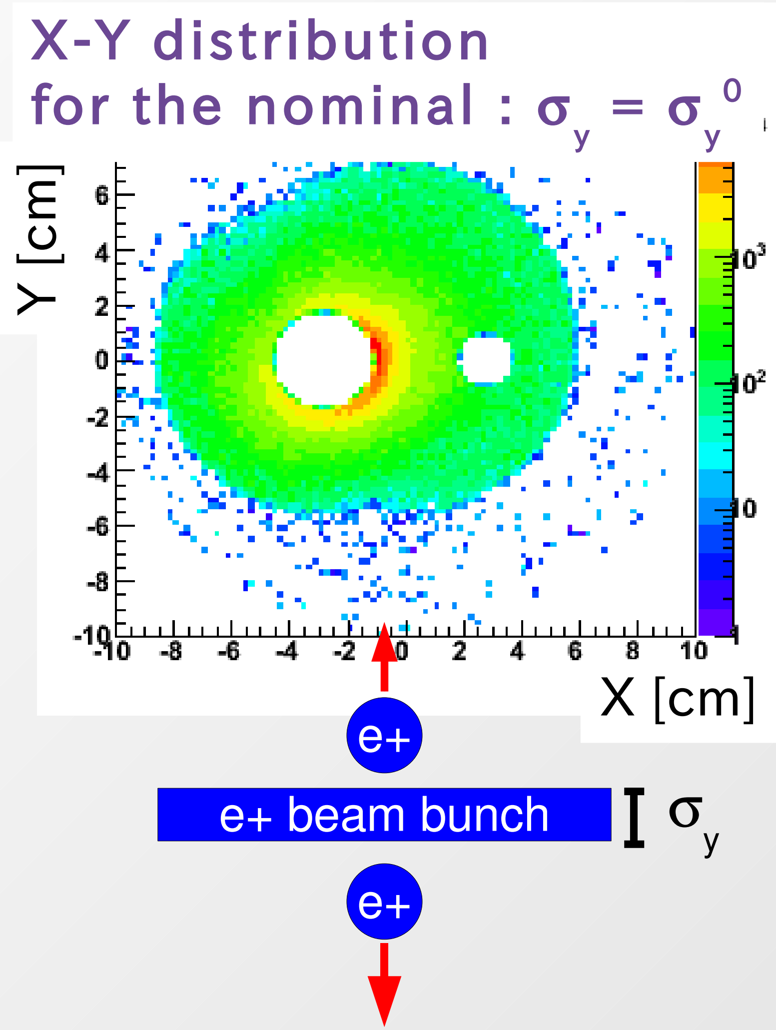


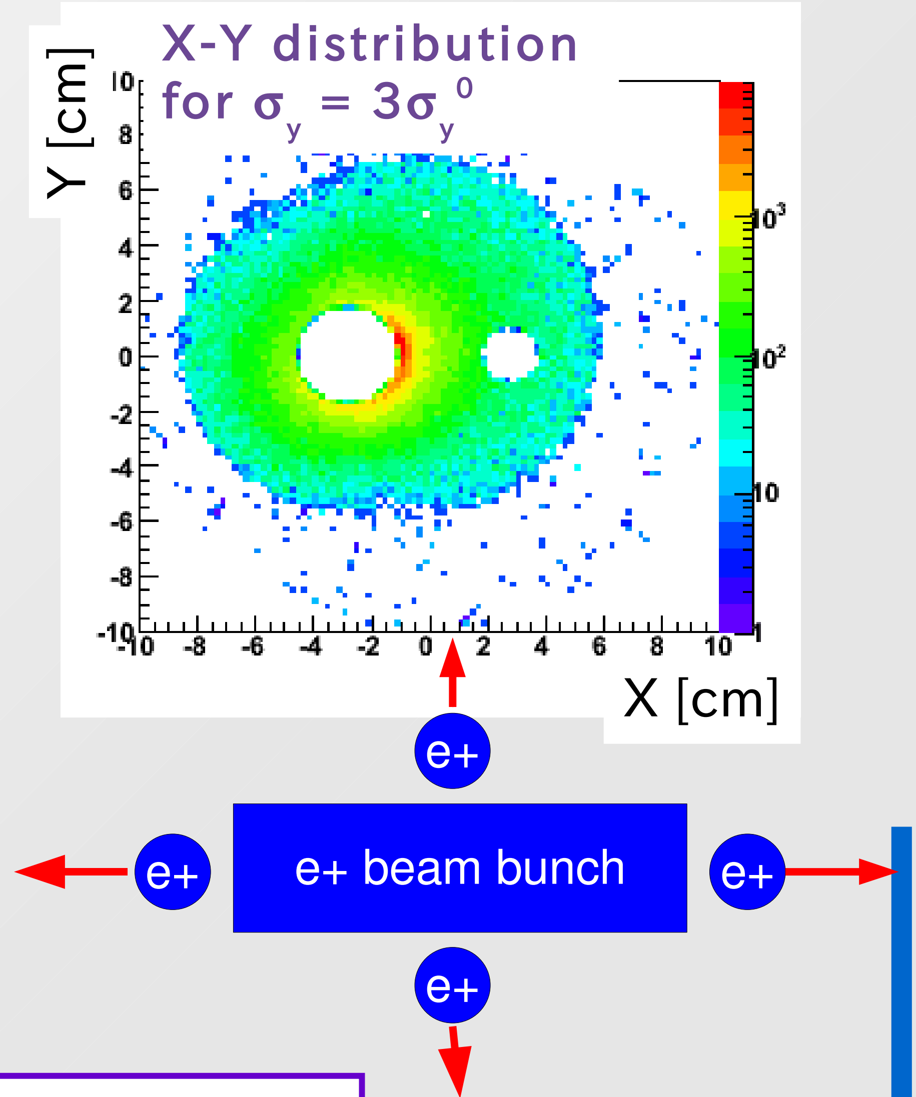


The statistical error is scaled to that of 164 bunches.
Horizontal beam size (σ_x) can be measured by resolution of 0.96 nm for the nominal beam size.

Measurement of vertical beam size (σ_y)

- The hit distribution changes with σ_y.



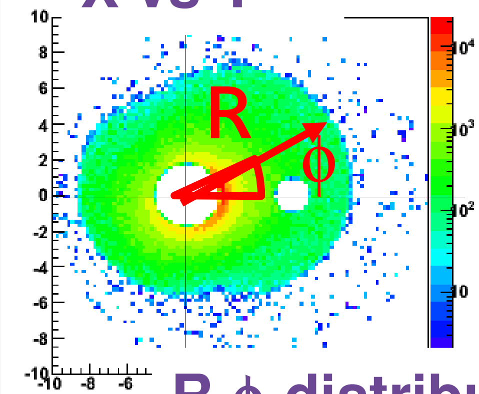


How get the information of σ_y ?

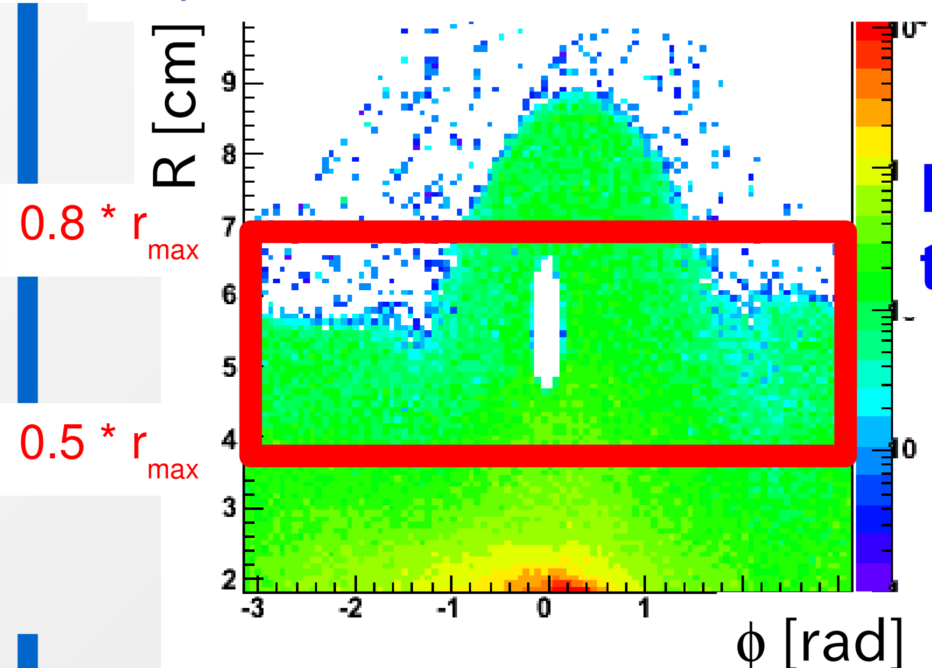
Locations of σ_y information

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

X vs Y



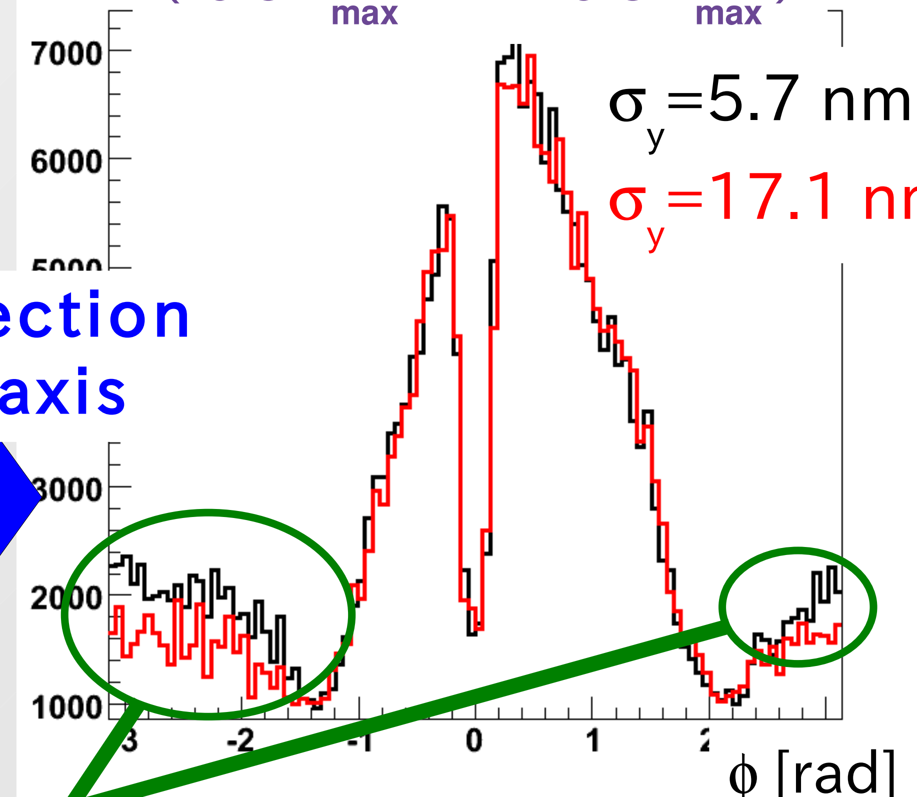
R-ϕ distribution for the nominal



Projection to ϕ-axis

ϕ distribution

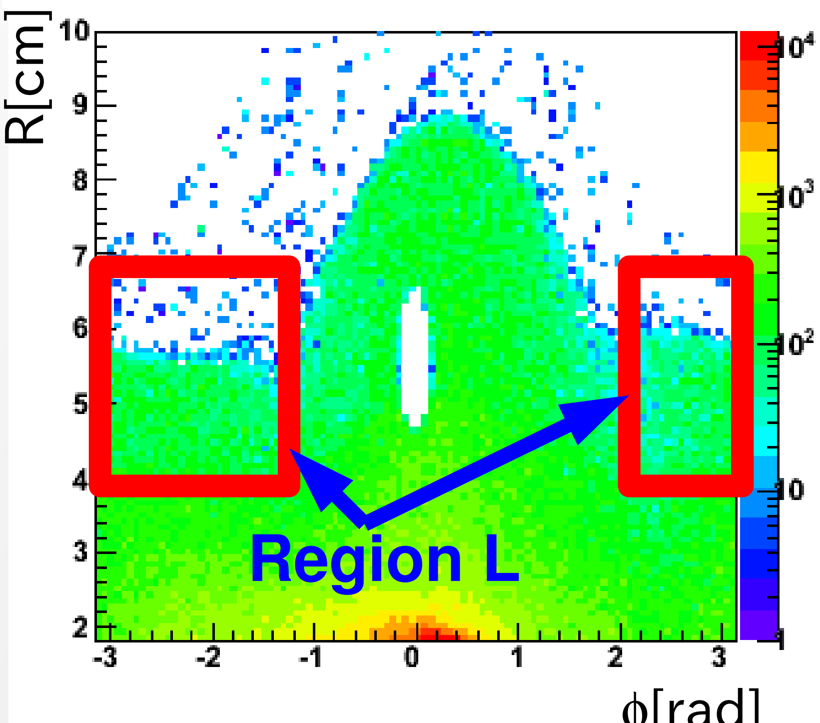
($0.5*r_{max} < R < 0.8*r_{max}$)



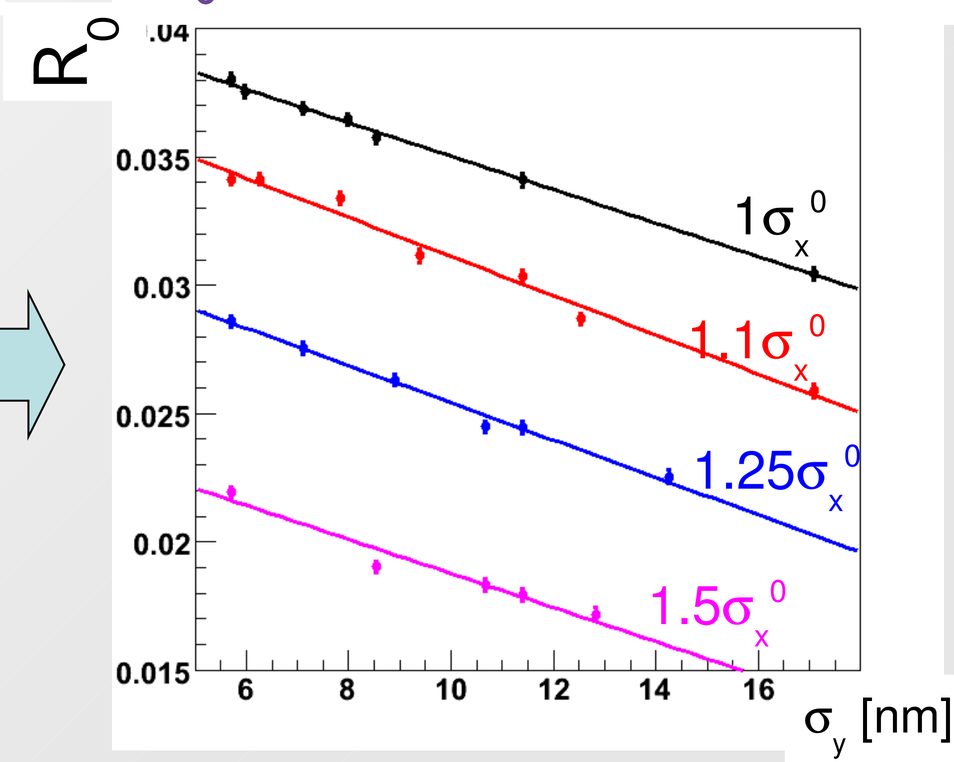
There is the information of σ_y in this region.

Resolution of vertical beam size (σ_y)

R-ϕ distribution for the nominal



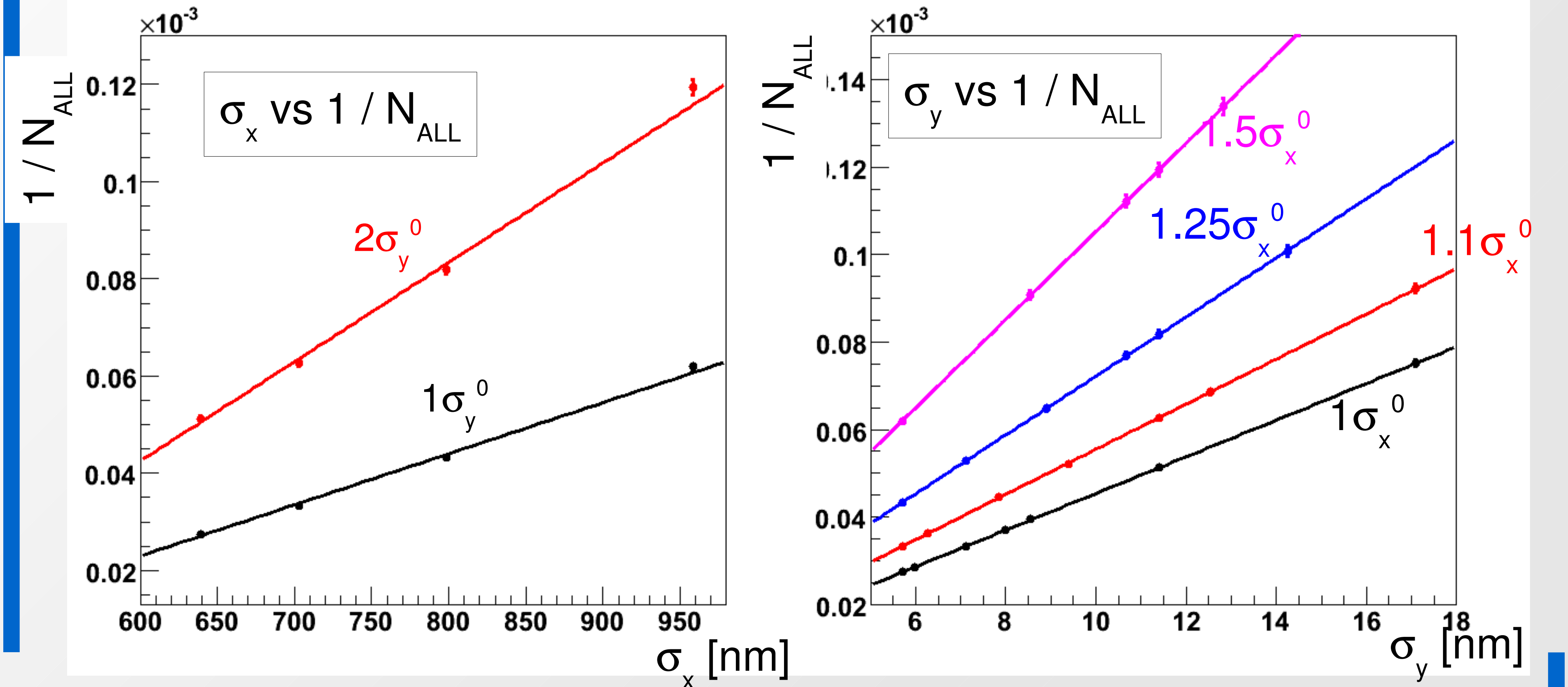
$R_0 = N_L/N_{ALL}$ (50 bunches)



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)

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

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

$$\downarrow$$

$$m = Ax$$

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

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

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

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

beam parameters.

measurements.

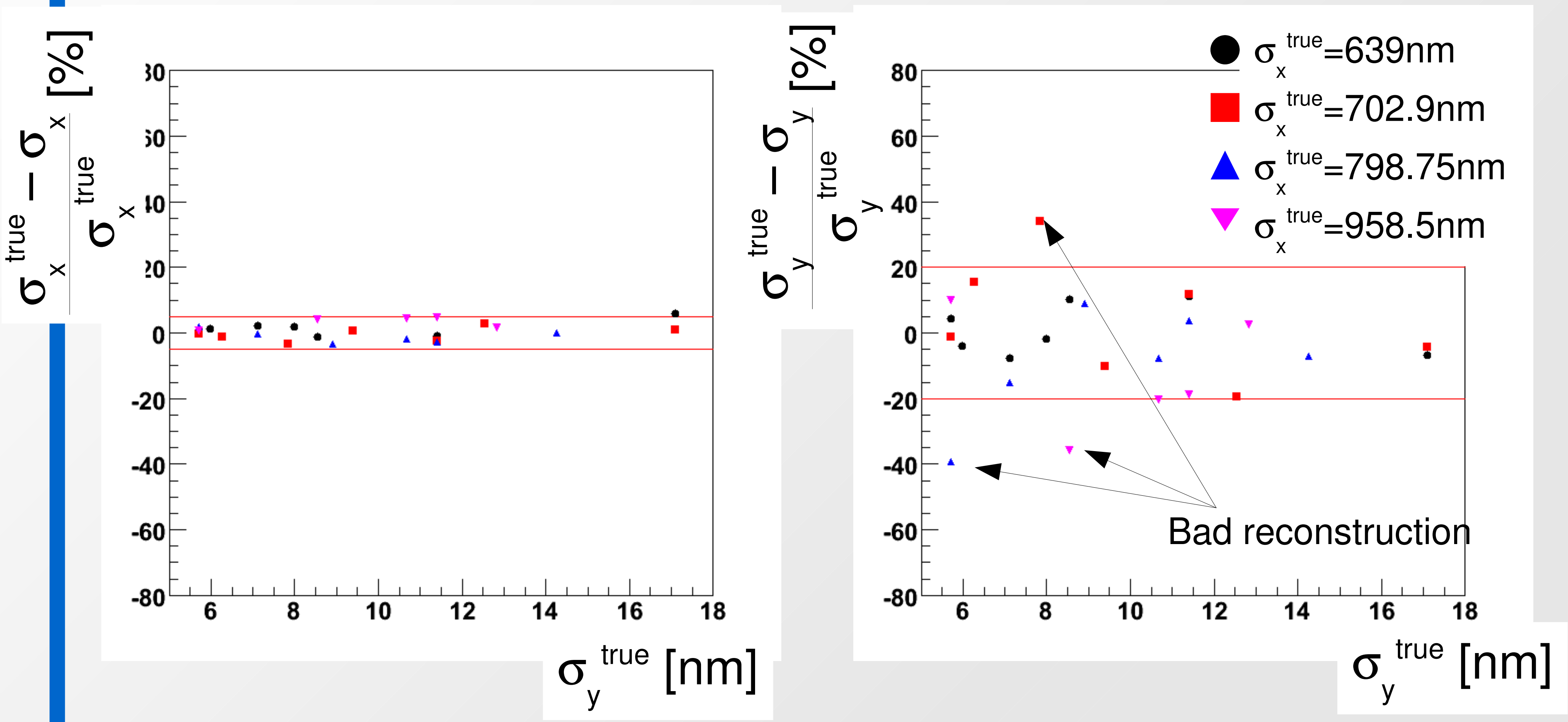
This matrix is made by fitting.

$$\downarrow$$

$$m = A x$$

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

Results



σ_x can be measure with 5%.

σ_y can be measure with 20%.

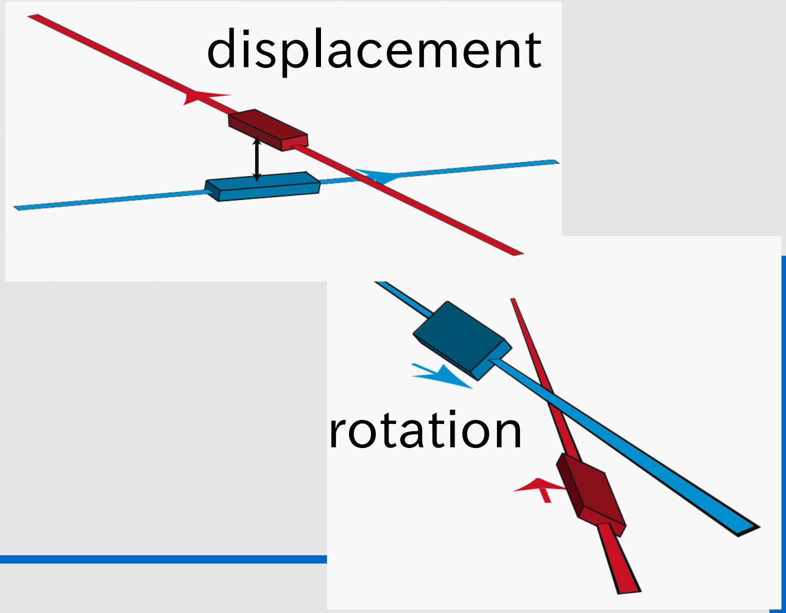
Measurement of σ_y should be improved to 10% accuracy.

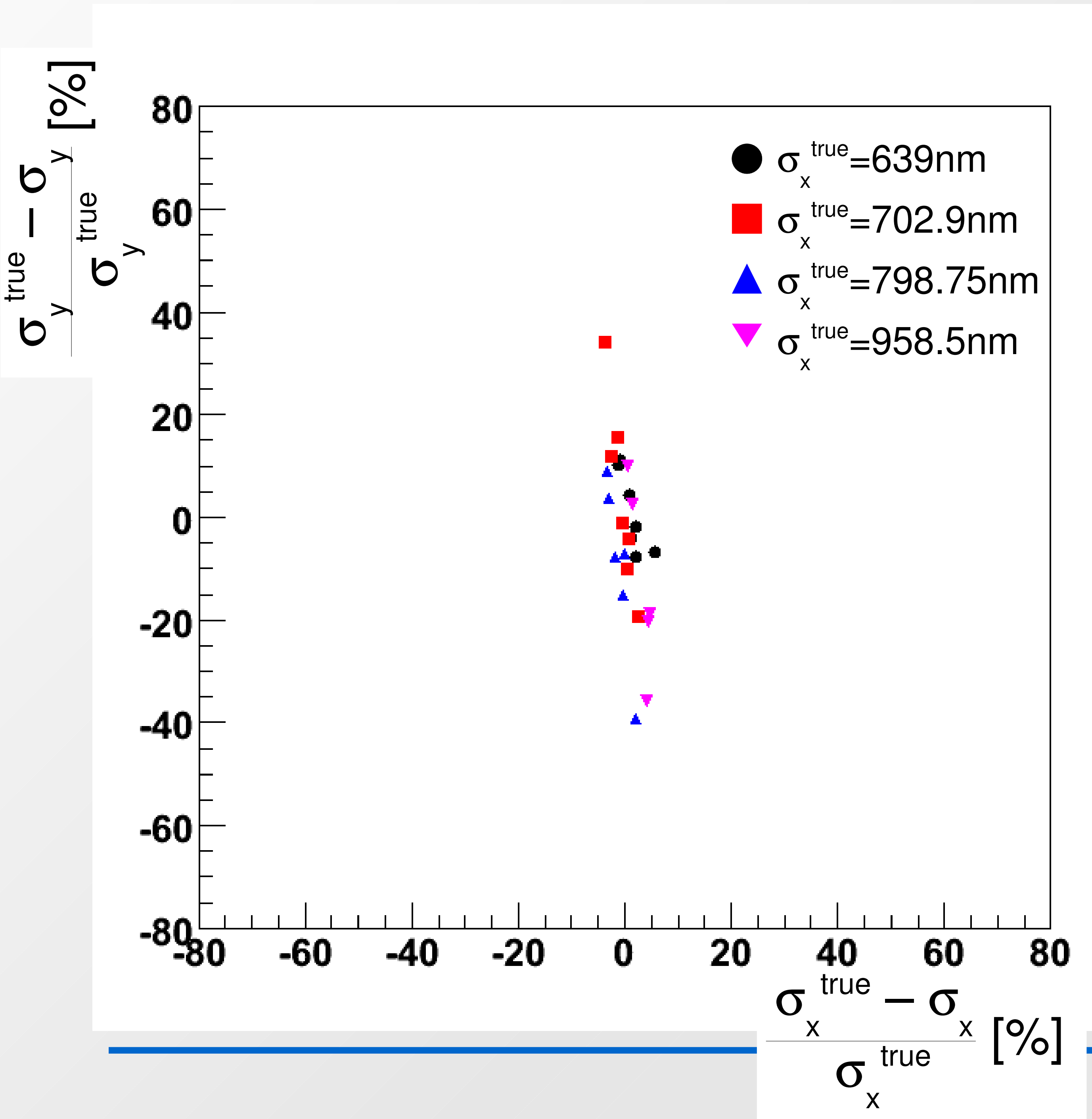
Conclusions

- Pair monitor measures the beam shape at IP.
  - Pair monitor is located at 400 cm from IP.
- Single parameter 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 0.96 nm for the standard beam.
- Double parameter measurement 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.
  - It can be used for ILD field.





80
60
40
20
0
-20
-40
-60
-80
-80
-60
-40
-20
0
20
40
60
80
$\frac{\sigma_y^{true} - \sigma_y}{\sigma_y^{true}}$ [%]
$\frac{\sigma_x^{true} - \sigma_x}{\sigma_x^{true}}$ [%]
σ_x^{true}=639nm
σ_x^{true}=702.9nm
σ_x^{true}=798.75nm
σ_x^{true}=958.5nm