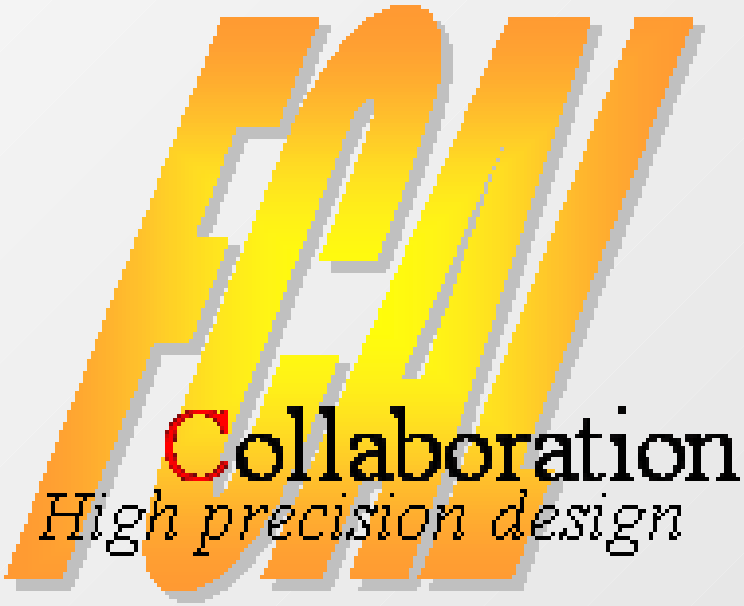
Simulation study of pair monitor



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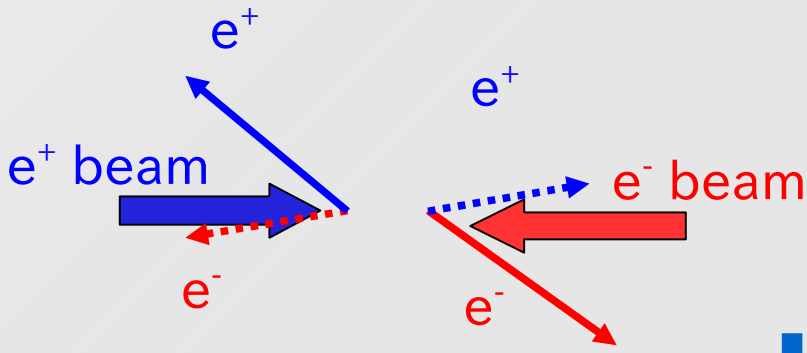
Introduction

- 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.

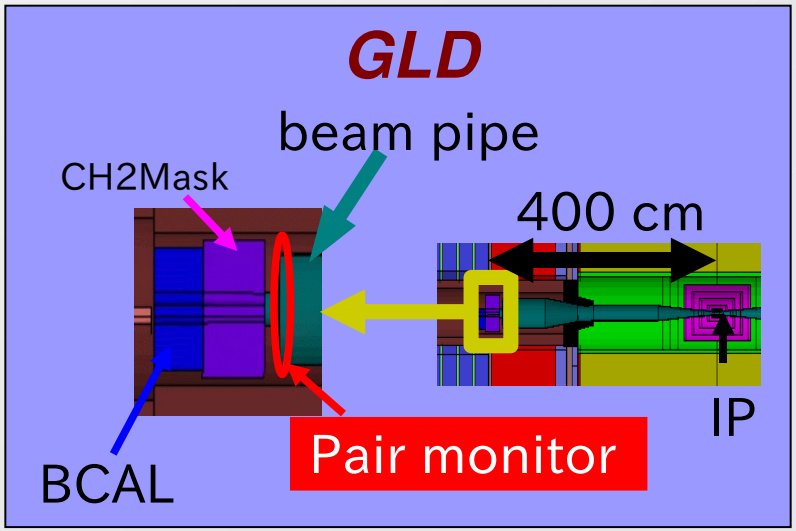


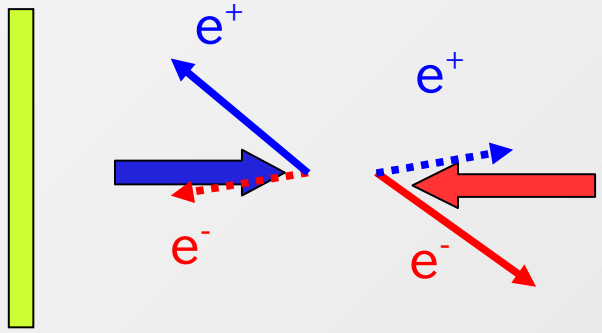
- Activity of Tohoku group.
  - Development of the readout ASIC.
  - Simulation study.

Current status of simulation study is shown.

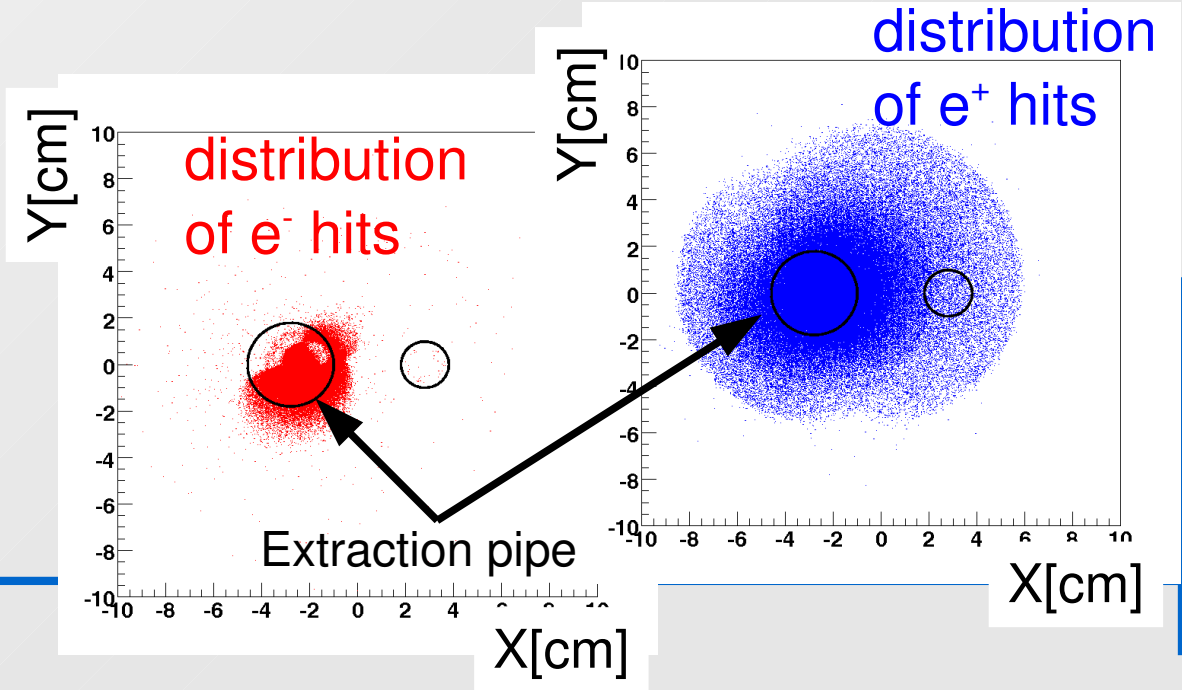
Simulation setup

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





Pair monitor



Matrix method for beam size reconstruction

- The beam size is reconstructed by the second order of Taylor expansion.

matrix of the first order term

matrix of the second order term

$$\begin{pmatrix} m_1 \\ m_2 \\ \vdots \\ m_n \end{pmatrix} = A \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix} + \left(\sigma_x, \sigma_y\right) B \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix}$$

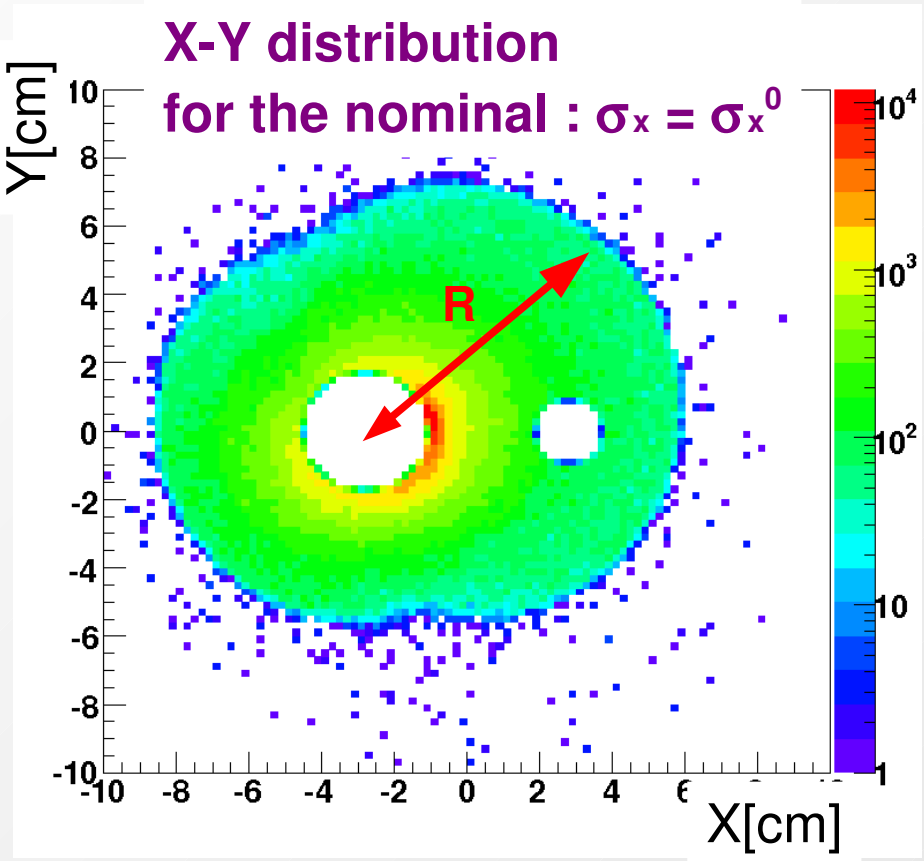
measurement variables (m)

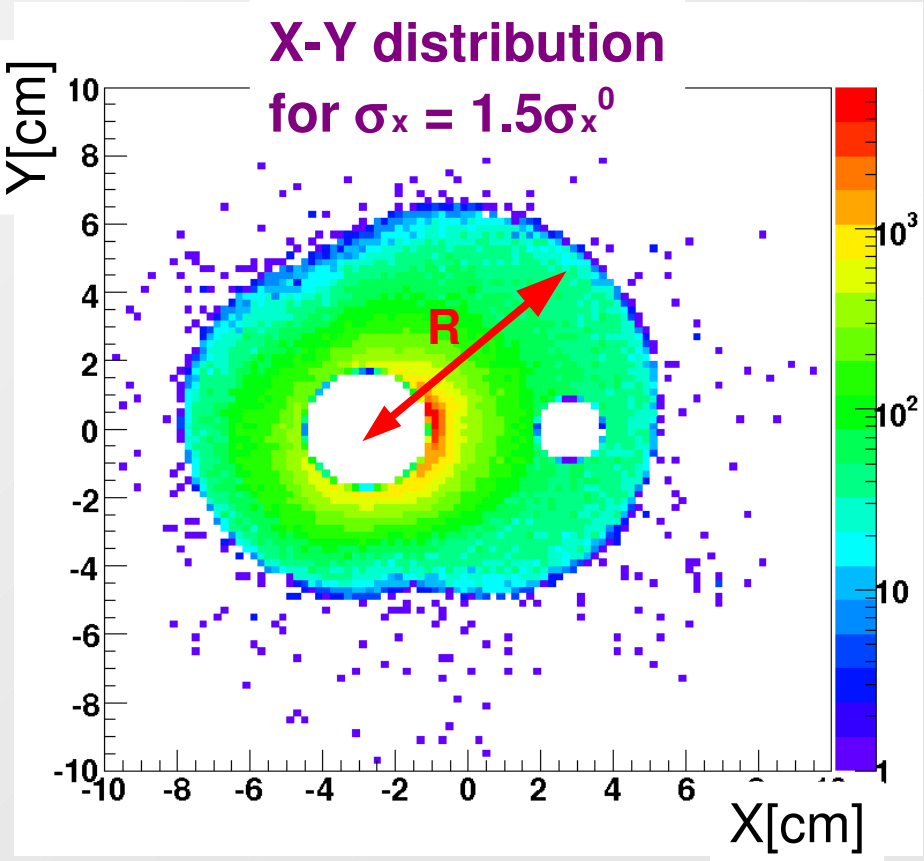
The beam size is reconstructed by the inverse matrix.

$$x \equiv \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix} = [\, A + x^T B \,]^{-1} m$$

The measurement variables are studied.

Variable 1 : Rmax (sensitive to the horizontal beam size)



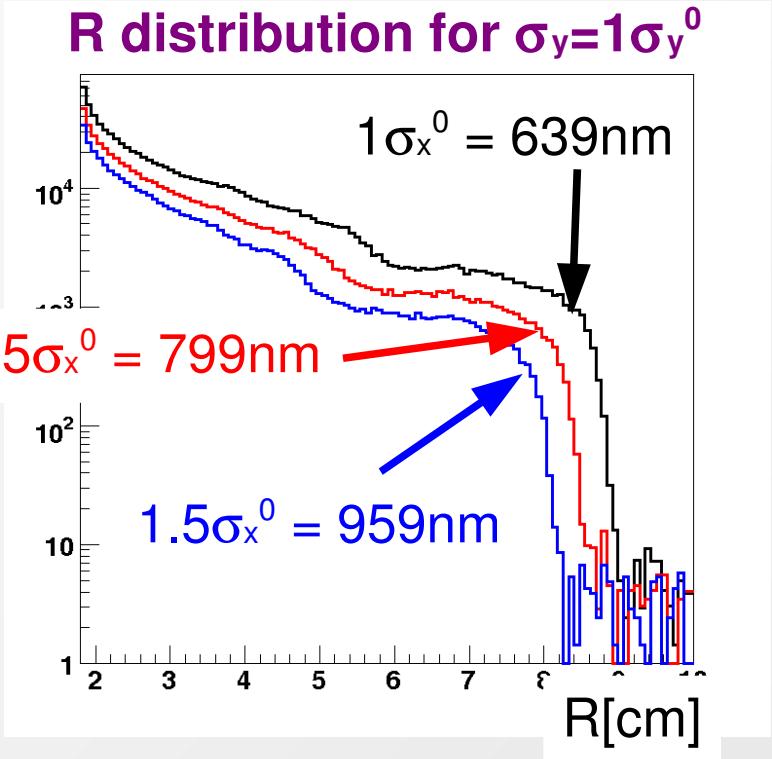


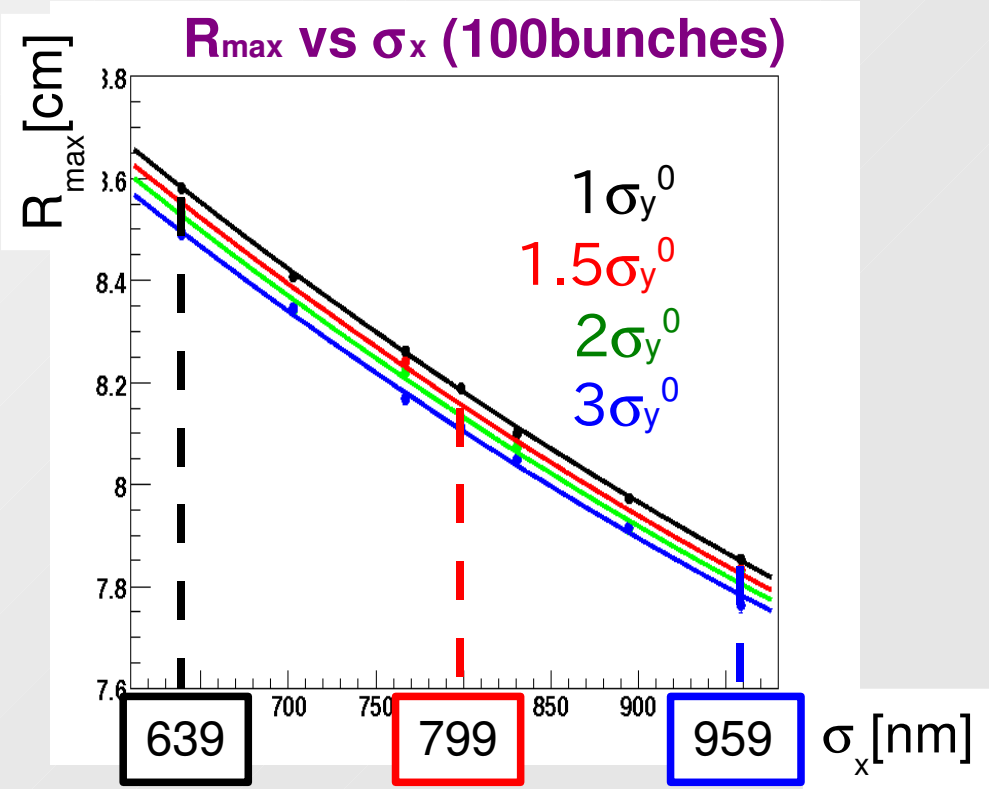
R distribution seems to depend on the horizontal beam size (σ_x).

The maximum R was investigated.

Variable 1 : Rmax

- R_{max} – Radius to contain 99.8% of all hits.

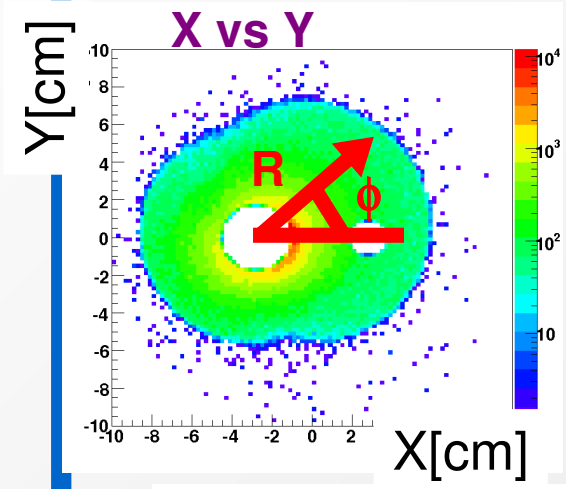




R_{max} depends on the horizontal beam size(σ_x).

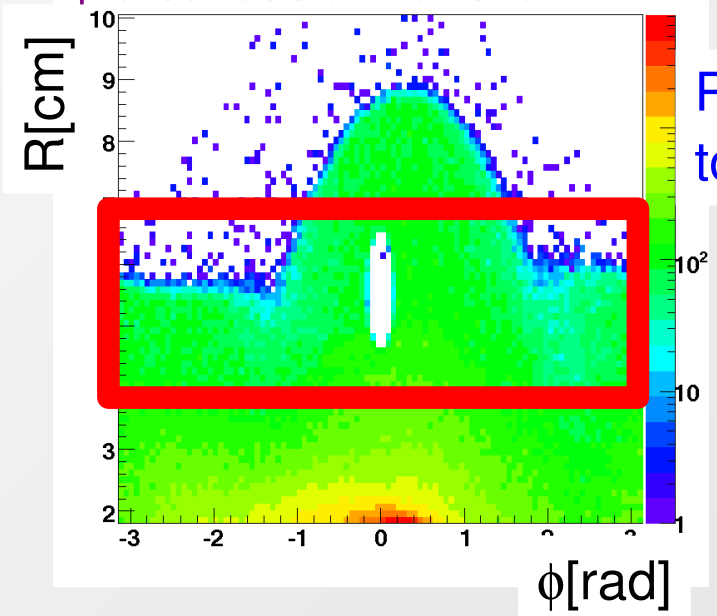
R_{max} can measure horizontal beam size(σ_x) with 1.7nm accuracy for the standard beam.

Variable 2 : Ratio (sensitive to the vertical beam size)

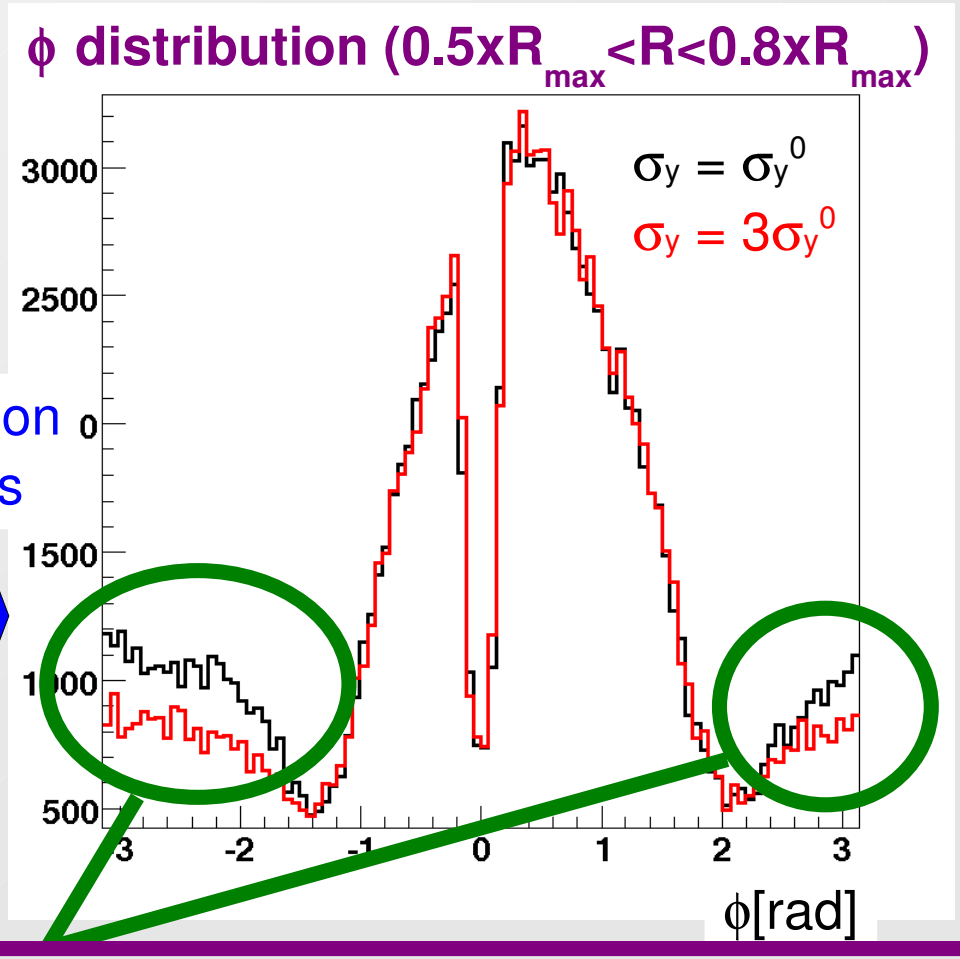


- To derive the beam information, projection to ϕ-axis is checked.

R-ϕ distribution for the nominal



Projection to ϕ-axis

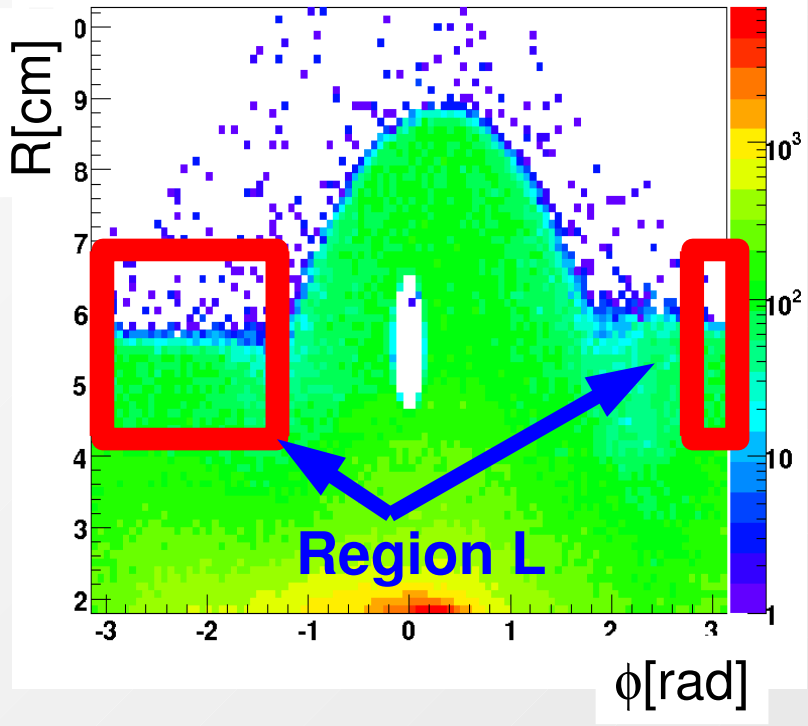


There is the information of σ_y in this region.

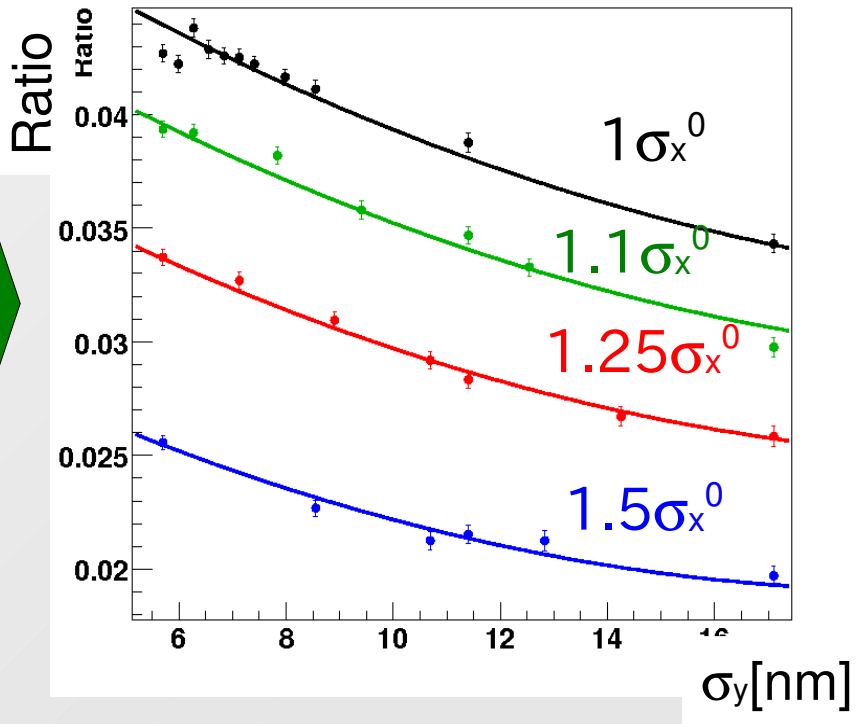
Variable 2 : Ratio

- The ratio defined N_L/N_{ALL} were obtained various beam size.

R-ϕ distribution for the nominal



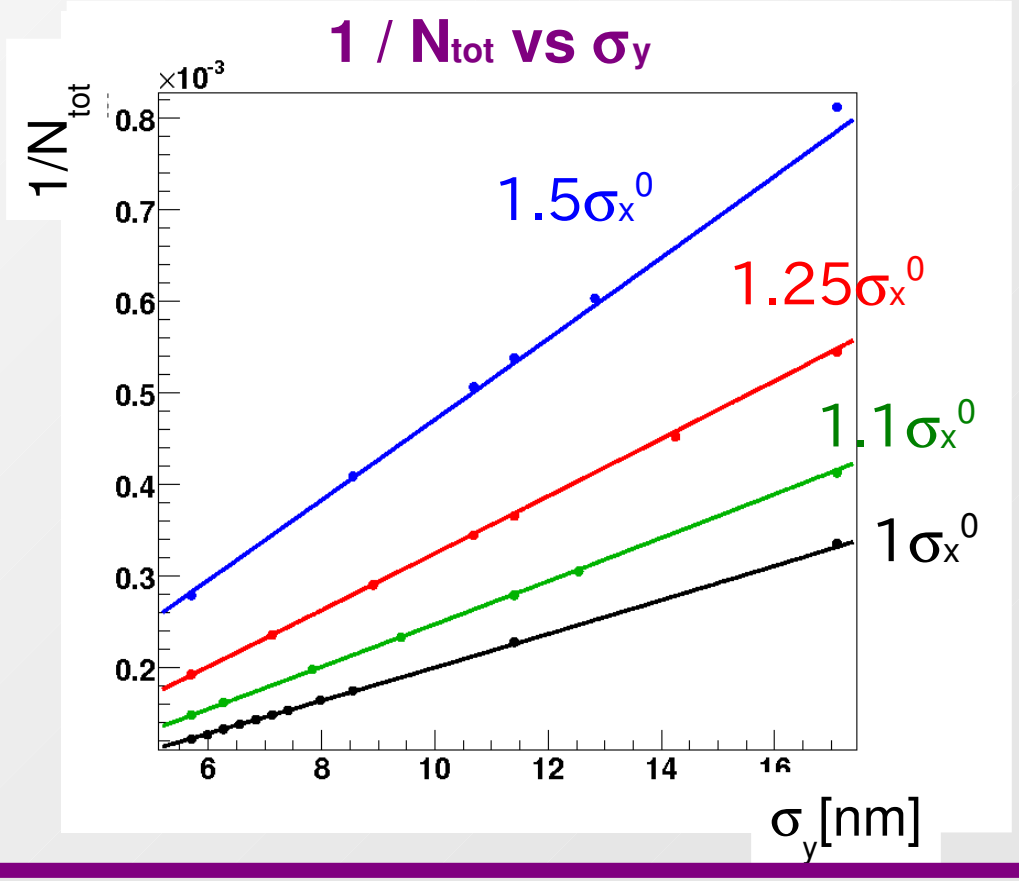
Ratio = N_L / N_{ALL} (100bunches)



The vertical beam size(σ_y) can be measured by resolution of 0.31nm(5.4%) for the standard beam.

Variable 3 : Total number of hits (sensitive to σ_x and σ_y)

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



$1/N_{tot}$ depends on both horizontal and vertical beam size.

Reconstruction of beam size

- R_{max}, Ratio, $1/N_{tot}$ were set as the variable term (m, A and B).

$$\begin{pmatrix} R_{max} \\ \text{Ratio} \\ 1/N_{tot} \end{pmatrix} = \begin{pmatrix} \frac{\partial R_{max}}{\partial \sigma_x} & \frac{\partial R_{max}}{\partial \sigma_y} \\ \frac{\partial (\text{Ratio})}{\partial \sigma_x} & \frac{\partial (\text{Ratio})}{\partial \sigma_y} \\ \frac{\partial (1/N_{tot})}{\partial \sigma_x} & \frac{\partial (1/N_{tot})}{\partial \sigma_y} \end{pmatrix} \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix} + (\sigma_x, \sigma_y) B \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix}$$

matrix of the second order term

measurement variables (m)

matrix of the first order term A

$$x \equiv \begin{pmatrix} \sigma_x \\ \sigma_y \end{pmatrix} = [\, A + x^T B \,]^{-1} m$$

- Procedure of the beam size reconstruction.

a) $x_0 = A^{-1} m$

b) $x_1 = [A + x_0^T B]^{-1} m$

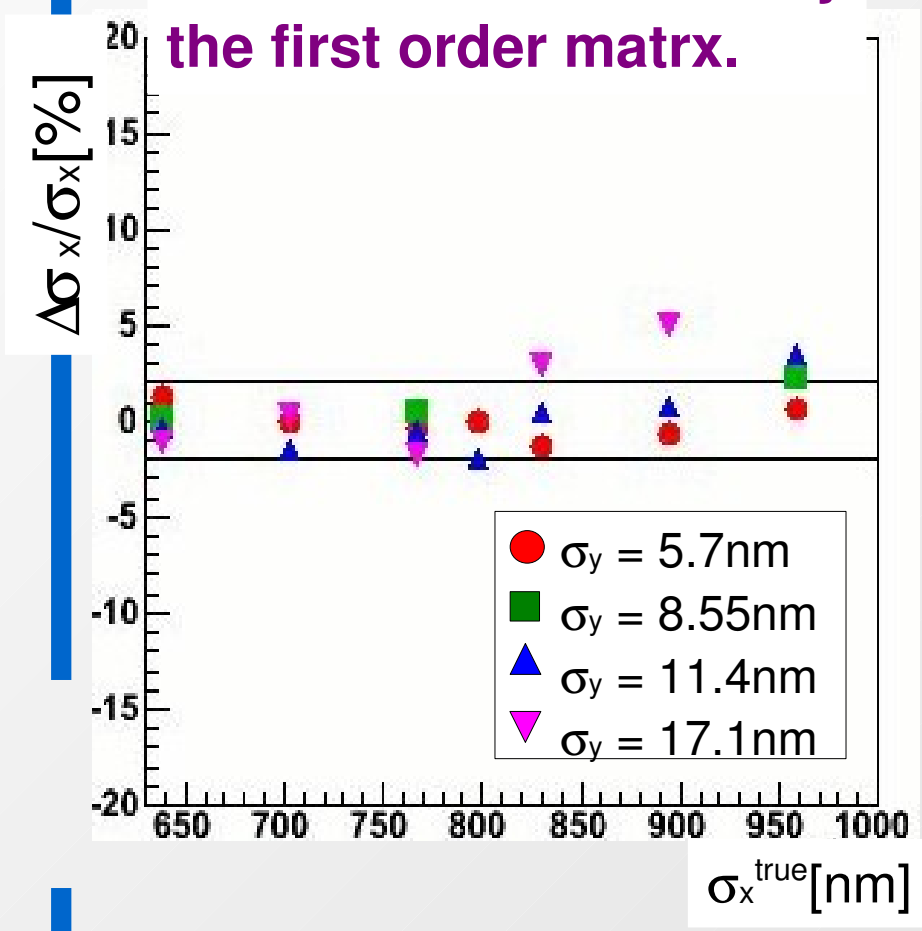
⋮

c) $x_n = [A + x_{n-1}^T B]^{-1} m$

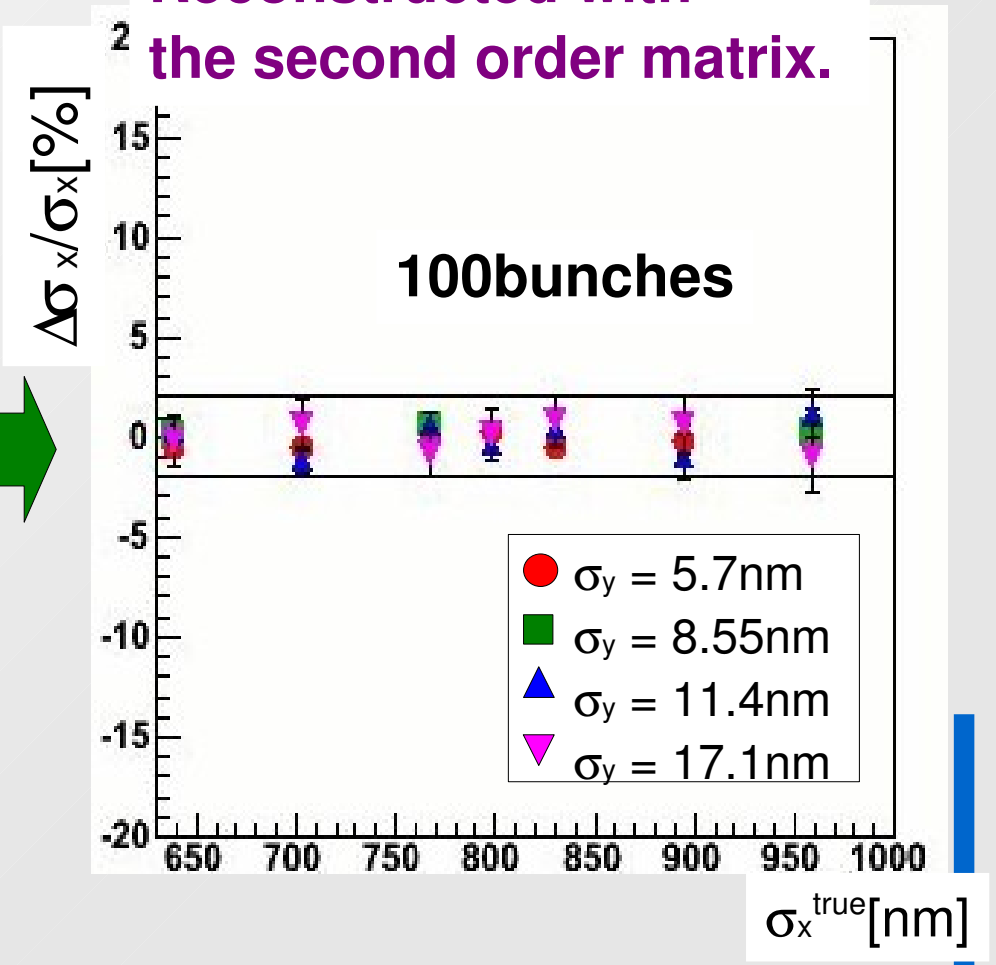
Results of the horizontal beam size reconstruction

measurement of the horizontal beam size (σ_x)

Reconstructed with only the first order matrx.



Reconstructed with the second order matrix.

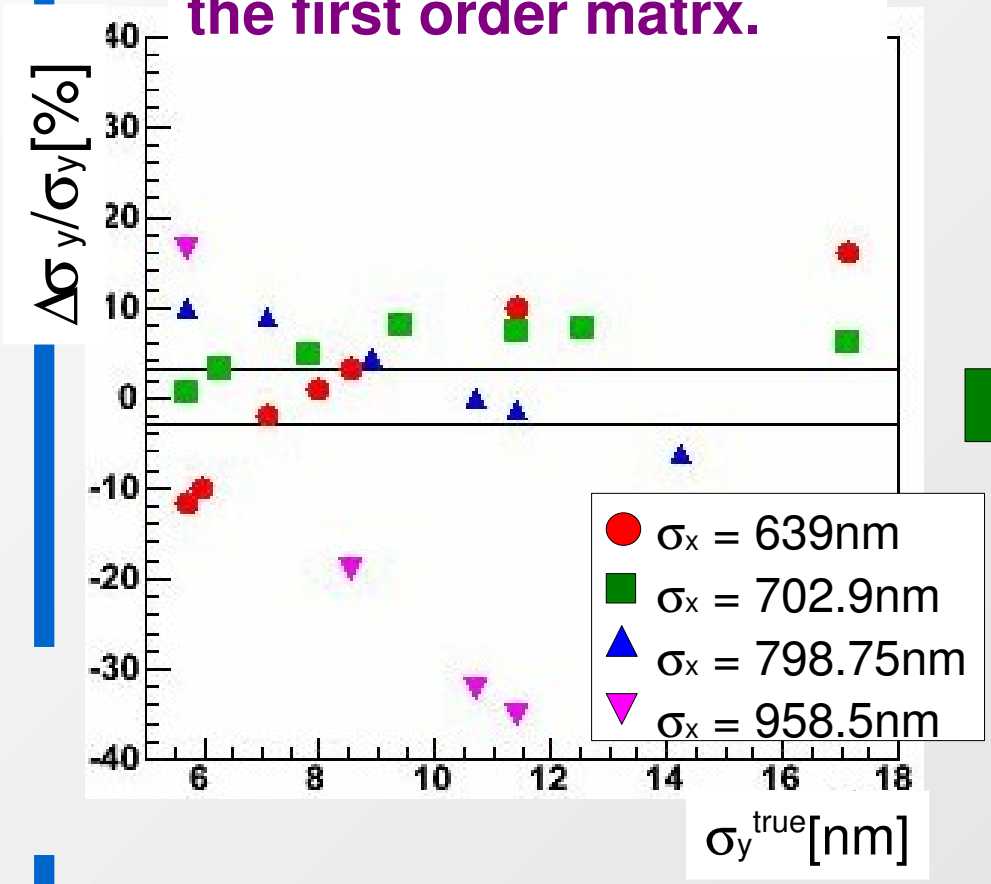


- Horizontal beam size can be measured with 2%.

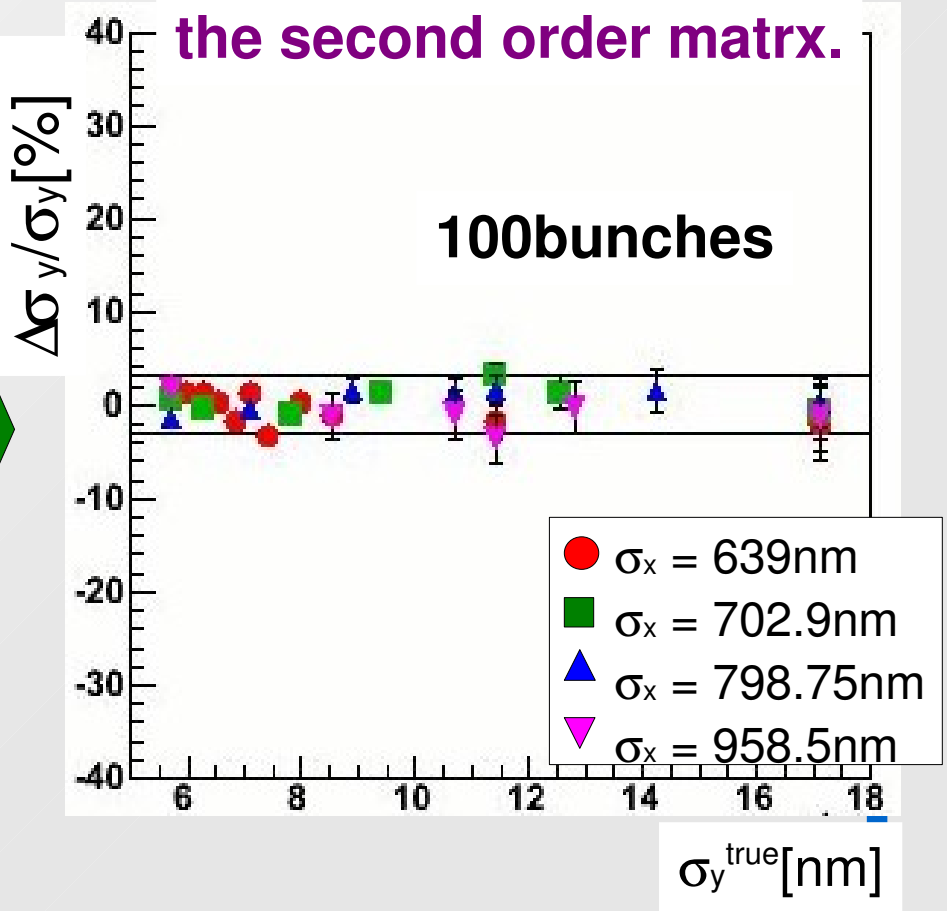
Results of the vertical beam size reconstruction

measurement of the vertical beam size (σ_y)

Reconstructed with only the first order matrx.



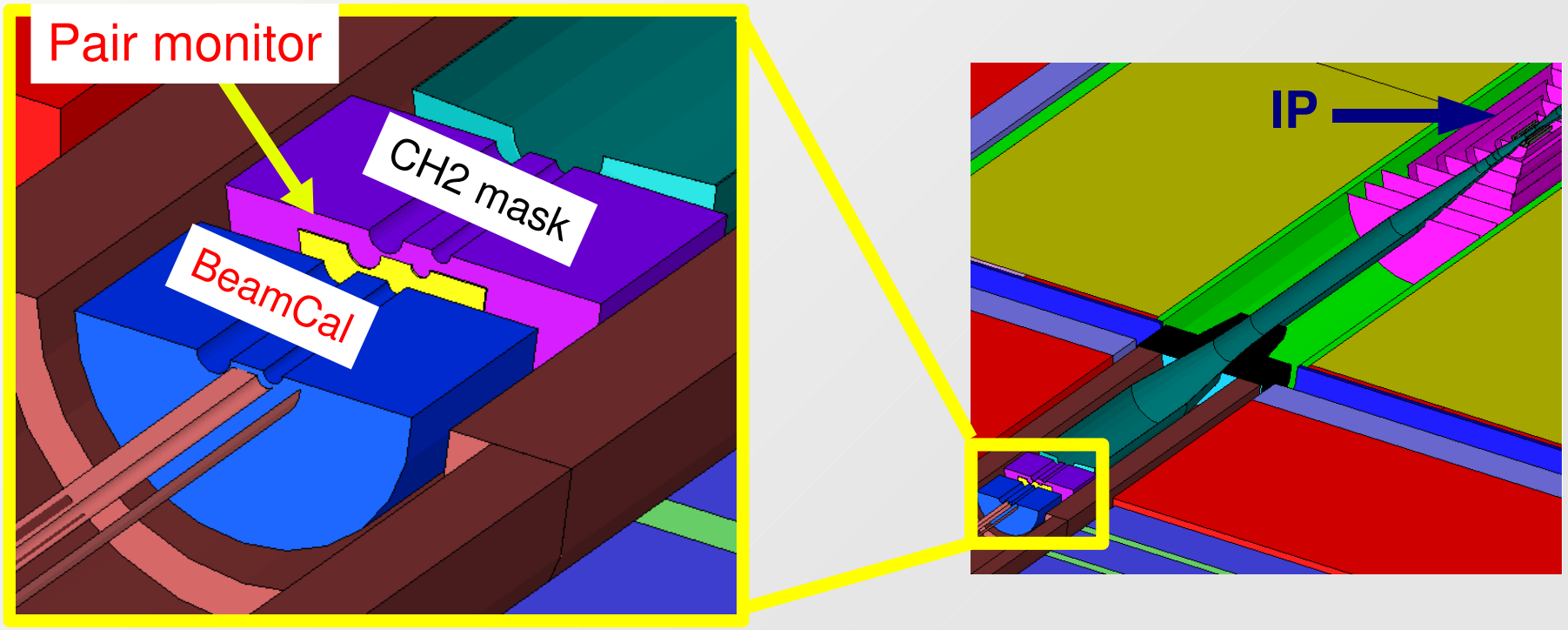
Reconstructed with the second order matrx.



- Vertical beam size can be measured with 3%.

Study for ILD

- We started the simulation study of Pair monitor for ILD.
- Pair monitor is inserted as the first layer of the BeamCal.
  - Pair monitor : Si of 200 μm thickness.
  - BeamCal : 33 layers of 300μm-Si and 3.5mm-W.

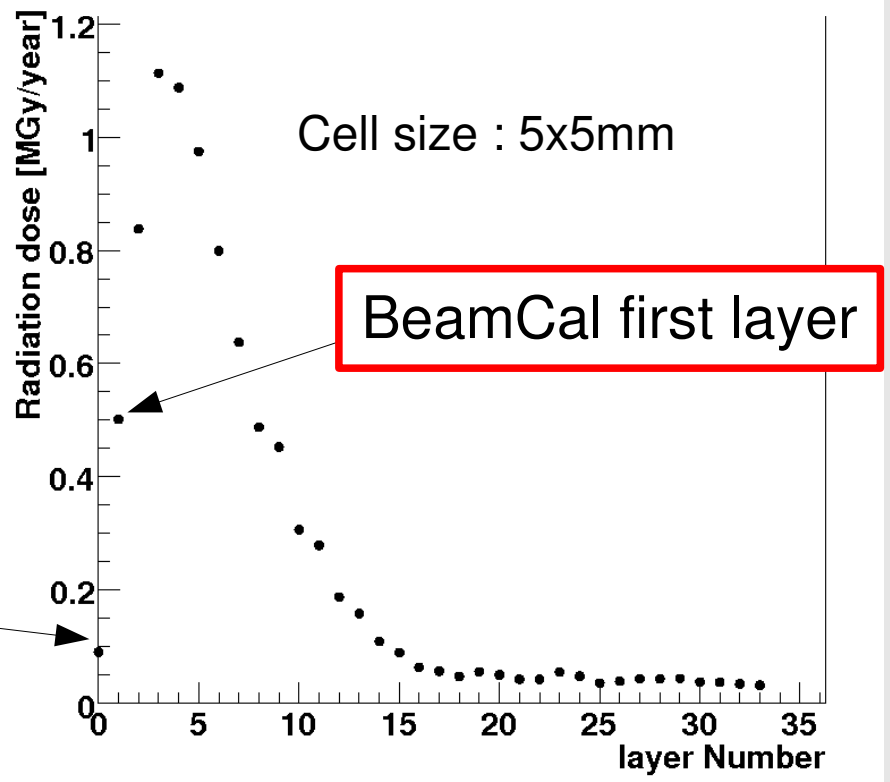


Radiation dose on Pair monitor and BeamCal

- The Radiation dose on Pair monitor and BeamCal for the nominal beam were checked.

- The dose at BeamCal third layer is maximum (1.1 [MGy/year]).
  - This value is consistent with the previous study (PRC07)
    - 4.3[MGy/year] for lowP
- On Pair monitor, the dose is 0.091[MGy/year].

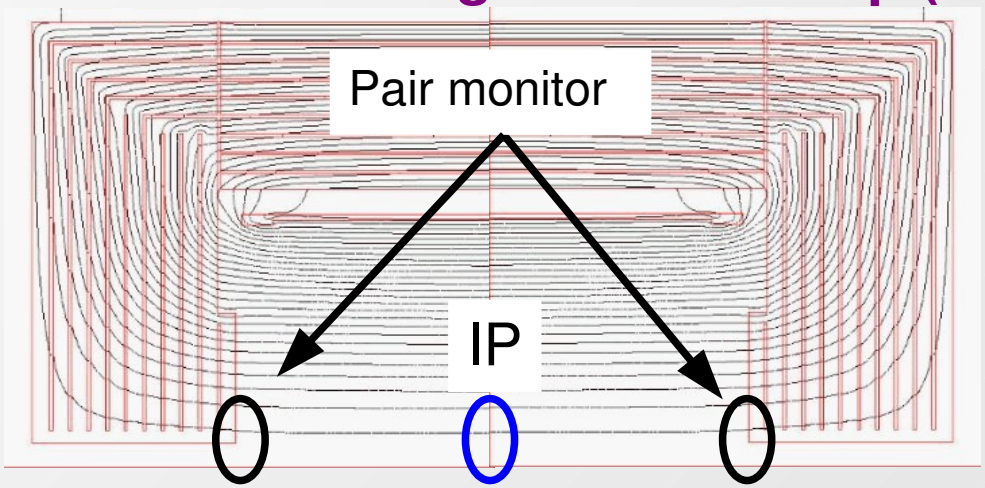
Radiation dose per year on Pair monitor and BeamCal

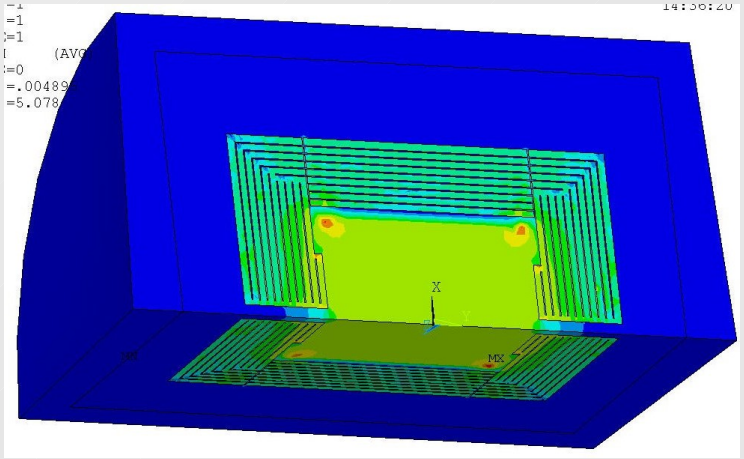


Preparing the 3-D magnetic field

- Preparation of the 3-D magnetic field is ongoing.
  - Software : ANSYS
  - The study is collaborated with Brett Parker.
- The current geometry is still GLD without anti-DID.
  - The next step is implementation of anti-DID.
  - It will be converted to ILD.

magnetic field map (solenoid field only)





The simulation with more accurate magnetic field will start as soon as the field map is prepared.

Summary

- Pair monitor measures the beam shape at IP.
- The beam size (σ_x, σ_y) were reconstructed using the matrix method (second order).
  - σ_x – resolution : 2% (~14nm).
  - σ_y – resolution : 3% (~0.2nm).
- Simulation study for ILD was started.
- We are preparing the 3-D magnetic field.

Plans

- Combined analysis with BeamCal.
- Simulation with more accurate magnetic field.

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.