CEPC LumiCal design and R&D progress

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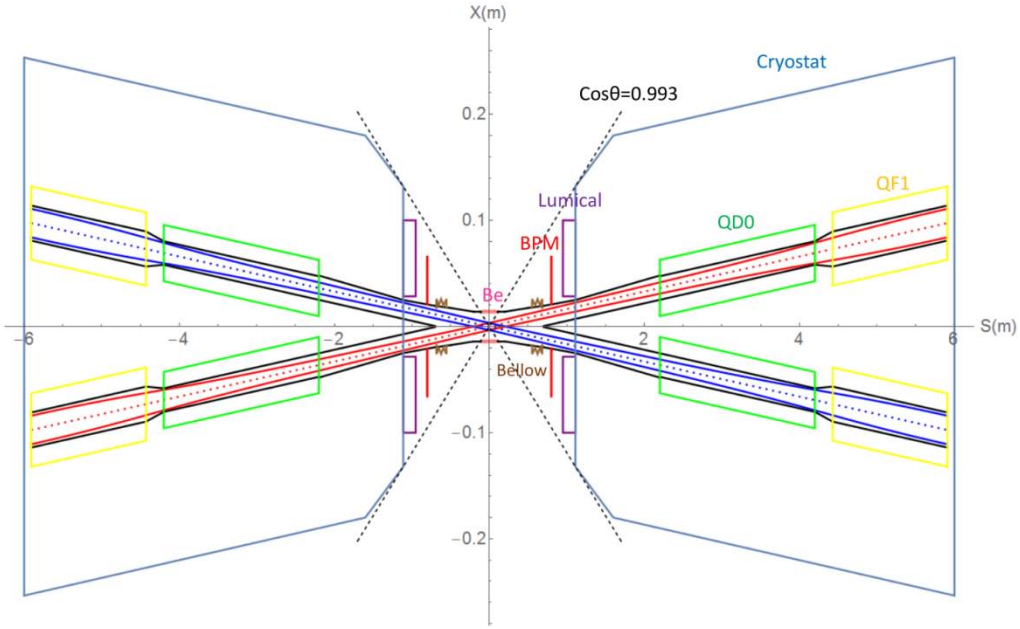
2018.11.14

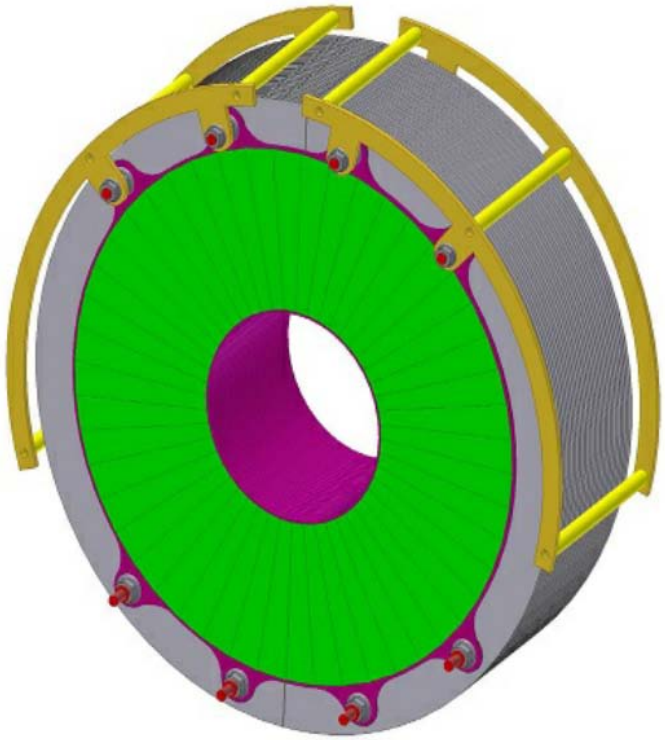
- LumiCal Geant simulation
- Detector segmentation and prototyping



LumiCal simulation

Liu YANG
Kai ZHU

Si-W of total 30 planes, $1X_0$ + 320 μm Si wafer
coverage 30 – 70 mRad at z = ±970 mm



Element	Value	Units
planes/module	30	-
tiles/plane	12	-
sectors/tile	4	-
cells/sector	64	-
Length	130.0	mm
Position(z)	±970	mm
inner radius	30	mm
outer radius	70	mm
layer gap	0.25	mm
sensor phi rotate	3.75	degree
silicon thickness	0.32	mm
support thickness	0.2	mm
tile gap	1.2	mm
tungsten thickness	3.5	mm

arXiv:1010.5992

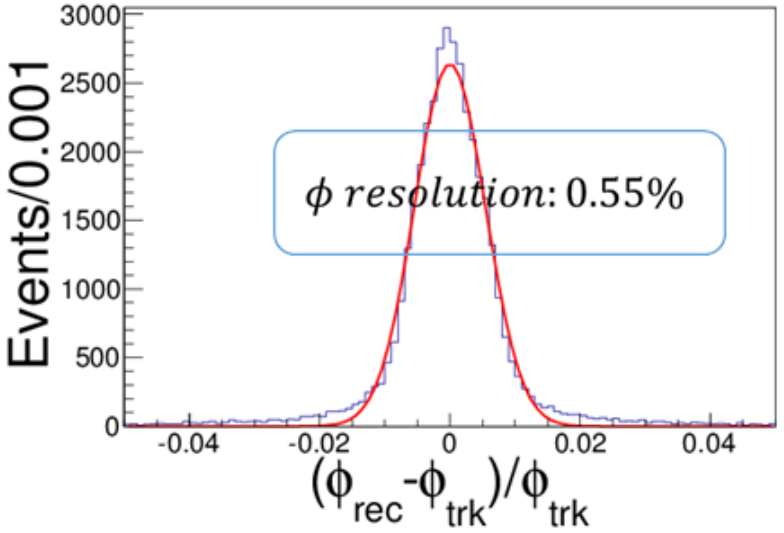
Electron shower Clustering

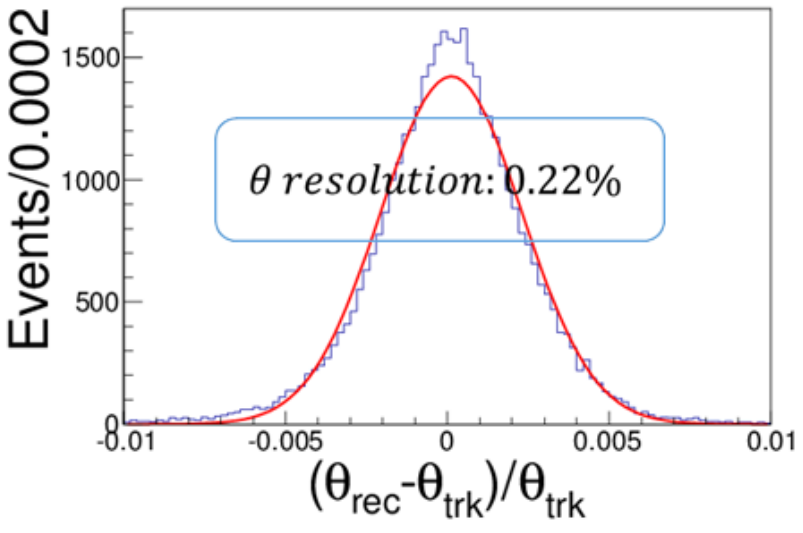
- Select shower-peak layers, 2-D clustering
- global cluster in 3-D → direction of electron track
  - Cluster center C is determined by **logarithm weight average** method

$$\mathbf{C} = \frac{\Sigma_i C_i W_i}{\Sigma_i W_i}$$

C_i: individual cell center W_i: $weight, W_i = \max(0,\ 5.5 + \ln\frac{E_i}{E_{all}})$

E_i: individual cell energy E_{all}: total energy in one global cluster.



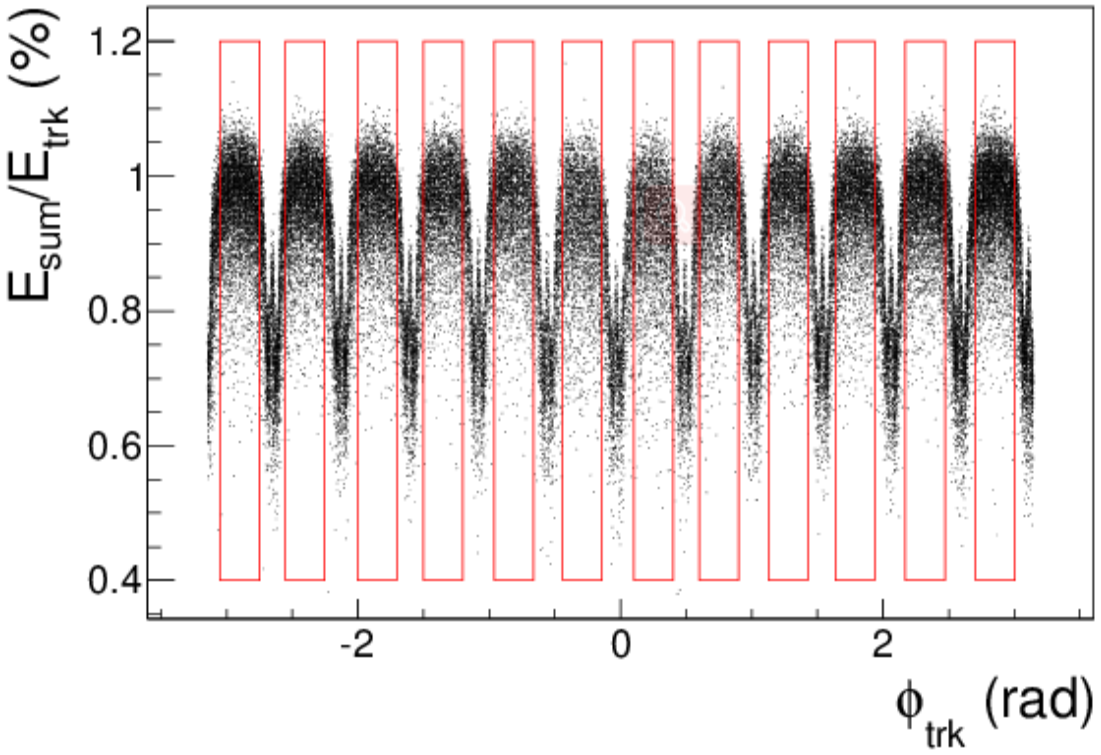


Shower containment in GEANT

Si samplers are in tiles with gaps

Cluster energy sum of energy deposits

➔ Shall make GEANT more realistic

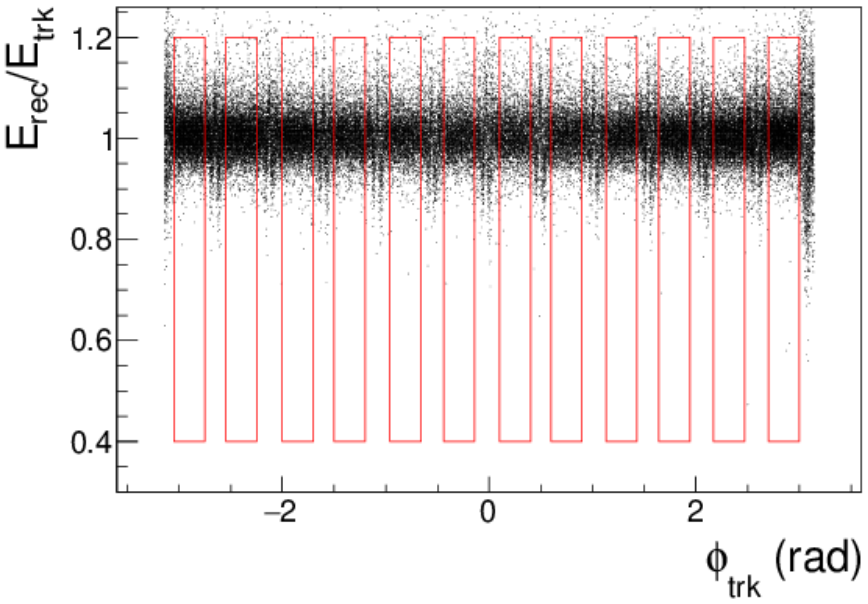


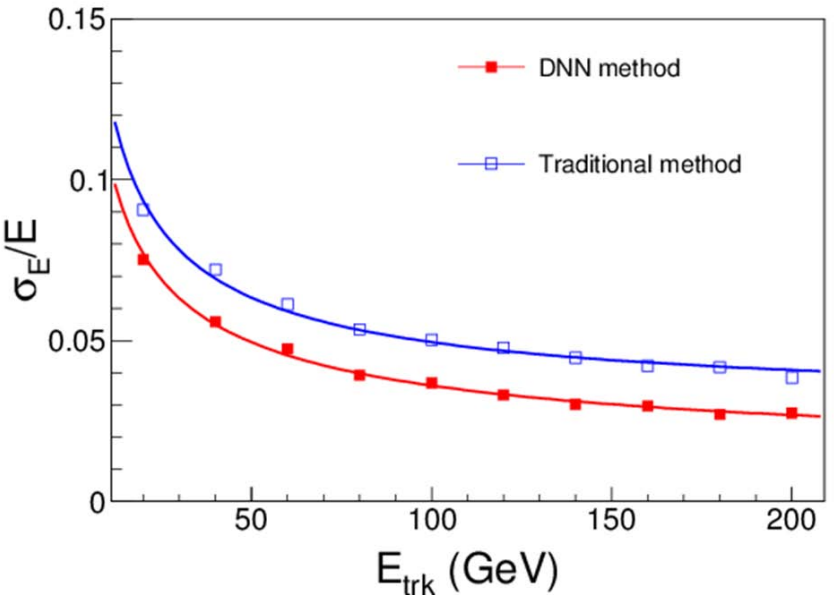
DNN to Partially contained shower

Deep Neutral Network
6 hidden layers

Training with 3×10^5 events
Random incident direction

DNN works well in tile gap region **improved energy resolution**





Luminosity measurement

- Z lineshape, $e^+e^- \rightarrow Z \rightarrow q\bar{q}$ is dominant, ***σ = 41 nb***
- Luminosity is by counting

  Bhabha, $e^+e^- \rightarrow e^+e^-$ elastics scattering

Counting Bhabha in a fiducial θ region

$$\mathcal{L} = \frac{1}{\varepsilon}\frac{N_{\mathrm{acc}}}{\sigma^{\mathrm{vis}}} \qquad \sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta^2_{min}} - \frac{1}{\theta^2_{max}}\right)$$

$\delta L/L \sim 2\,\delta\vartheta/\vartheta_{min}$

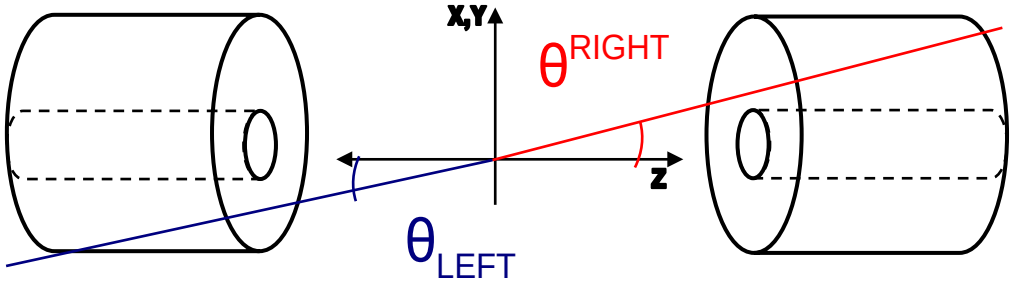
$\delta L/L < 10^{-3}$ at **z = ±1 m**

θ_{min} = **20 mRad**

→ *$\delta\vartheta$ = 10 µRad* or ***dr = 10 µm***

offset on Z

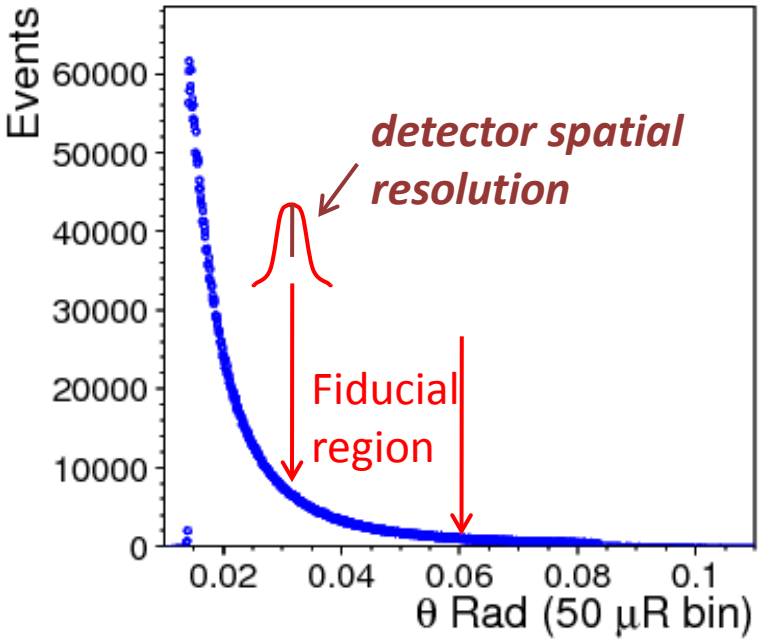
→ *1 mm on z* or ***dr = δz x ϑ = 20 µm***



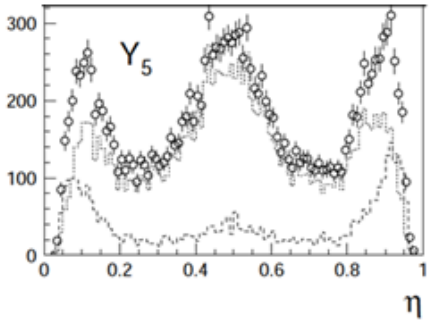
LumiCal precision with Si strips

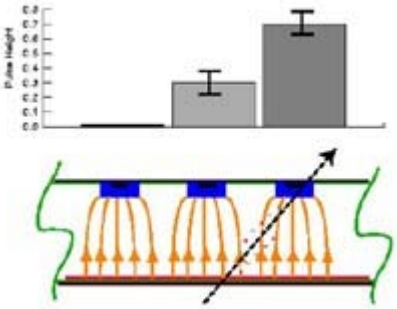
Precision is dominated by
at the fiducial θ_{min}
→ offset on the mean of **θ** at edge
→ **δ**N in event counting

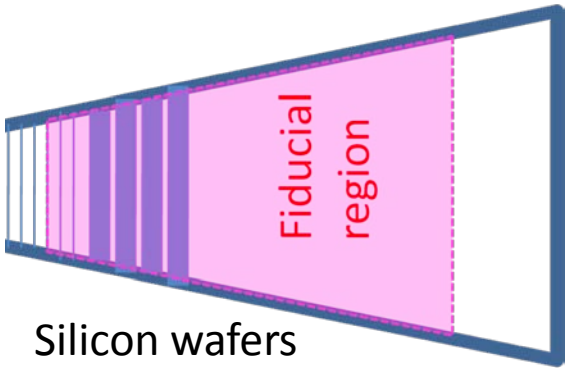
Fine pitch strips (50 um pitch) σ ~ 5µm
calibrate the σ shape
→ **Error on mean can reach zero**



$$\eta = \frac{Q_r}{Q_r + Q_l},$$



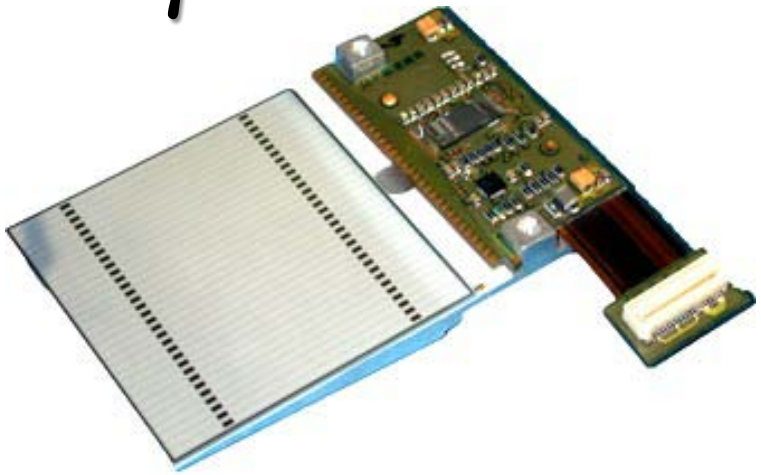




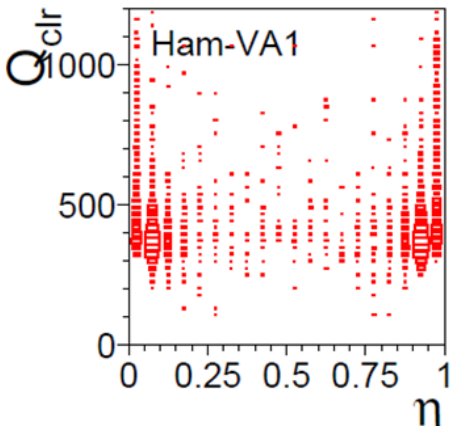
Silicon wafers
of micro-strips

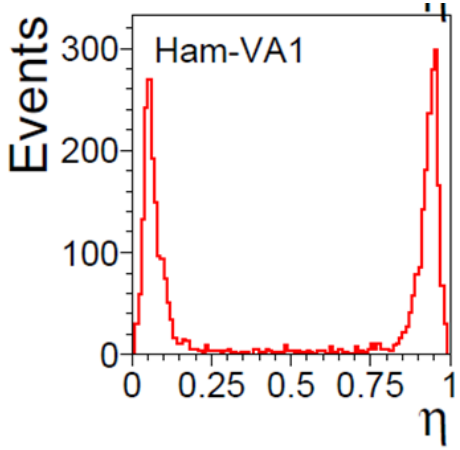
Problem with a wide Si strip

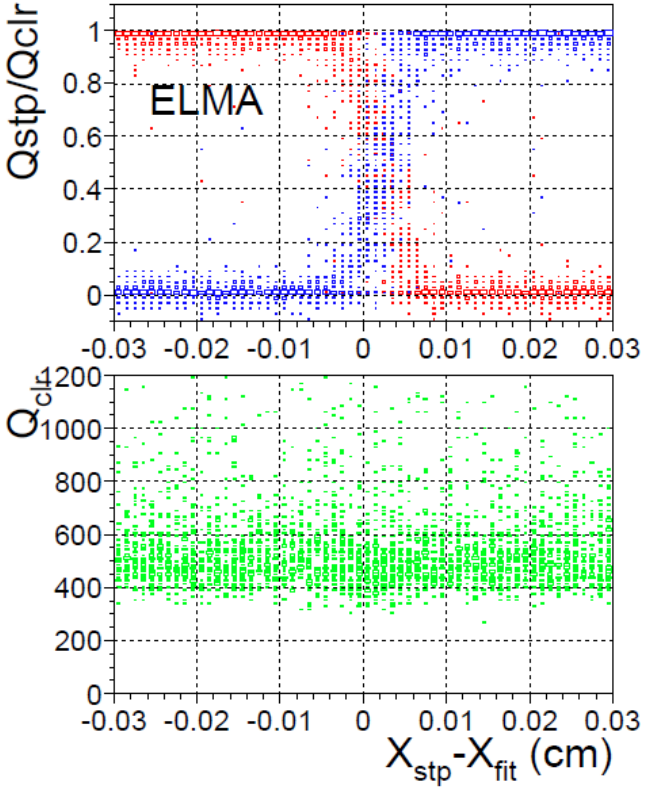
- wide strip pitch e.g. **2 mm**
  gap may be 100 μm
- Event counting at edge is difficult
  calibration of charge sharing
  can hardly reaching **10 *μm***



$$\eta = \frac{Q_r}{Q_r + Q_l}$$







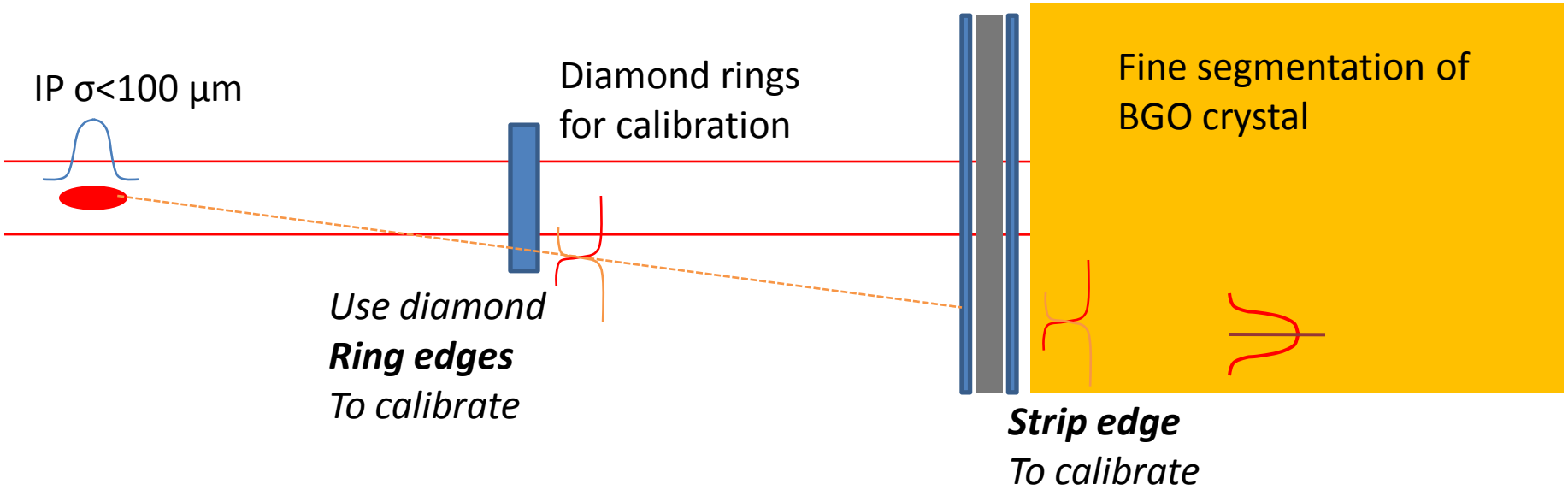
Survey of Lumical positon 3-points tracking

- IP + Diamond ➔ calibrate Lumi strip position
- Diamond + LumiCal ➔ measure IP size

Calibrate *offset* of the *mean of error* at inner radius

Silicon strip resolution ***~ 5 um,*** *error on mean* ***CAN reach 1 µm,***

➔ δL/L ~ 0.01 %

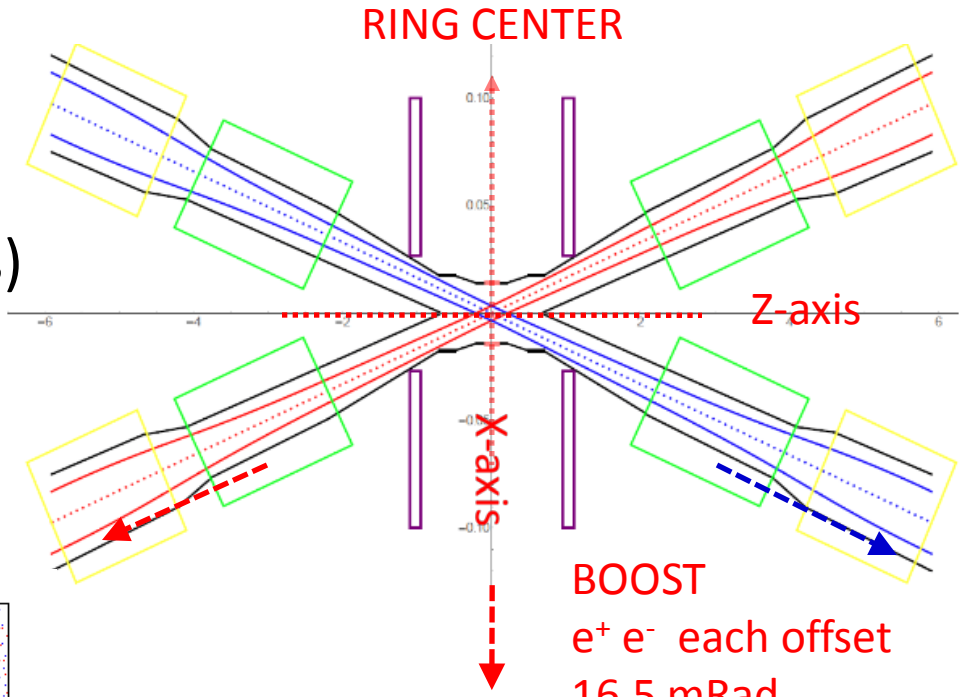


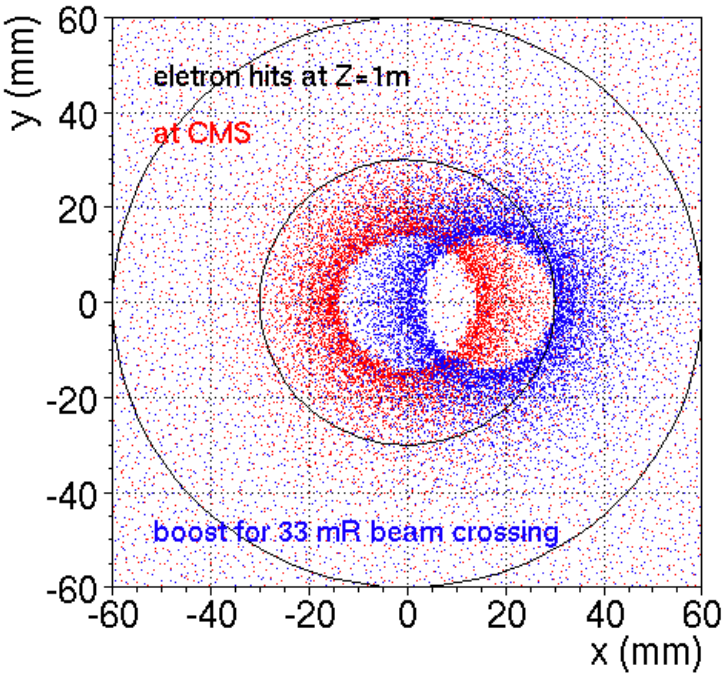
Boost effect to Bhabha and LumiCal

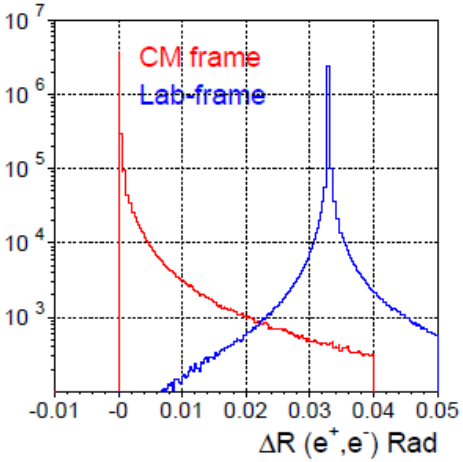
Beam crossing: 33 mRad

→ Boost off ring center (+x axis)

→ offset 16.5 mRad maximum
(electrons on x-z plane)



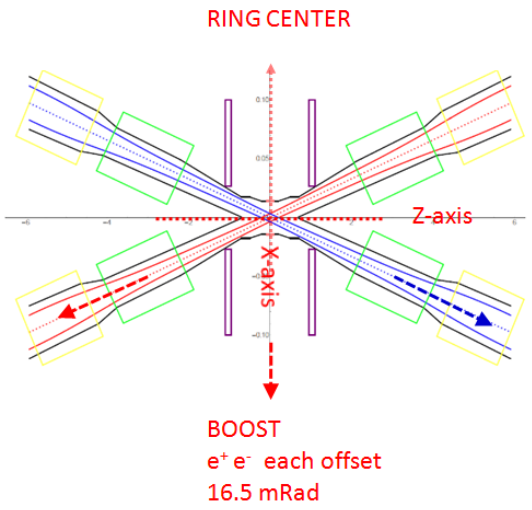


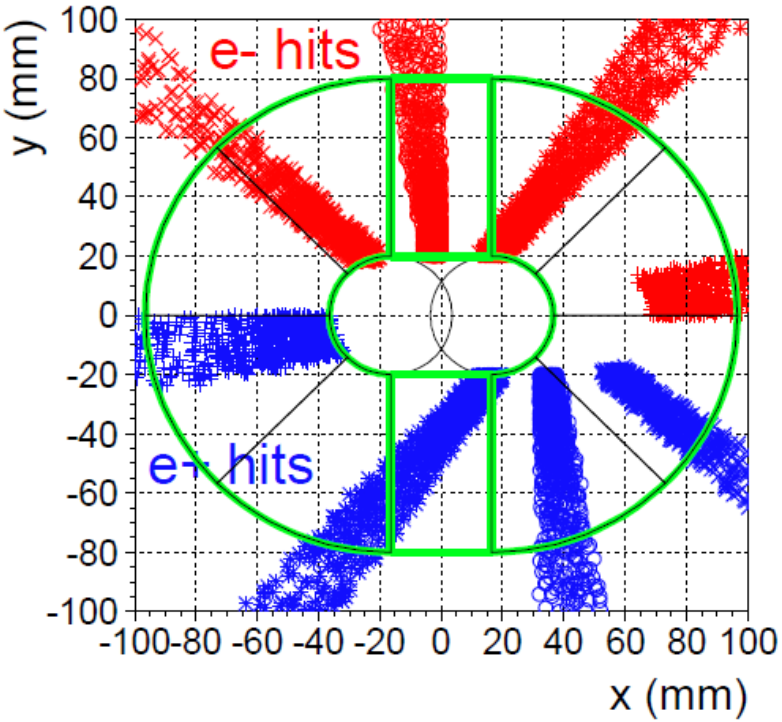


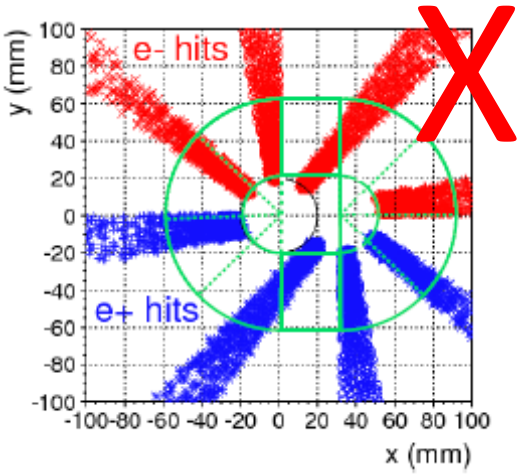
Segmentation of LumiCal

Scattered Bhabha electrons are
Centered to outgoing beam center

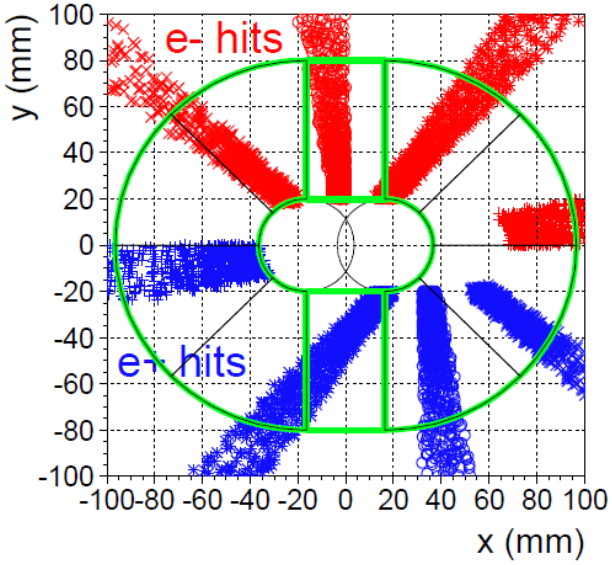
Same θ_{min}, CM frame to 33 mRad crossing
→ Bhabha back-back both e^+, e^- detected
→ acceptance loss 50%







Weight of a SiW Lumical



- Tungsten density 19.3 g/cm^3
- Radiation length 3.5 mm

SiW at CEPC at z = ± 1m

- a circular W layer of radius=100 mm
  3.14x10cm^{2}x.35cm x 19.3 = 2000 g
- a rectangular 10cm x3.3cm x.35cm x19.3 = 220 g
- a W layer = 2.5 kg
- a 25 layer detector = **62 kg**

Prototyping a SiW detector

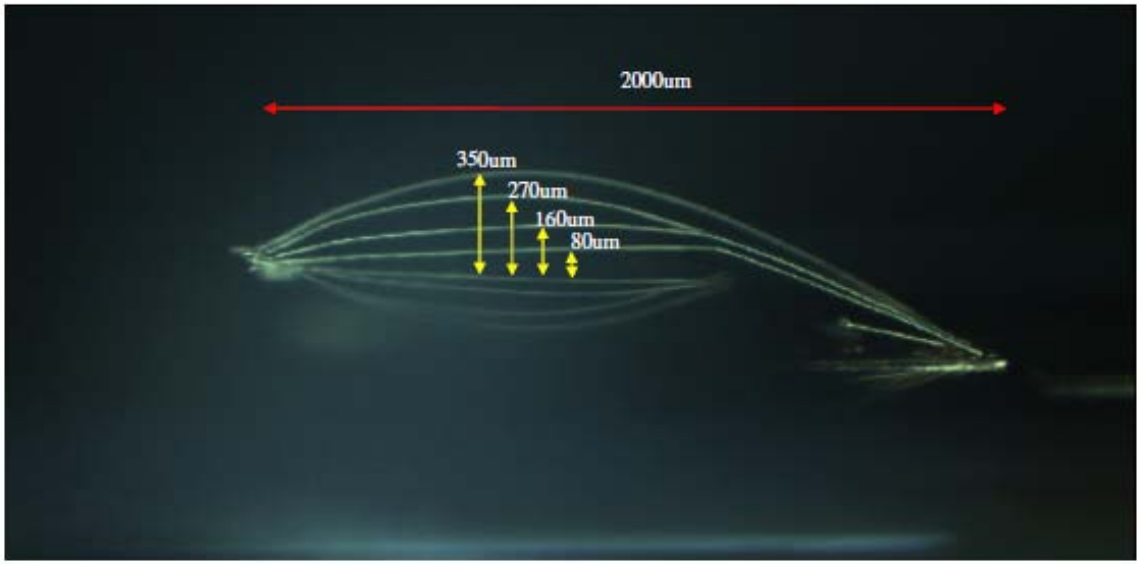
Use CMS preshower wafer

- wedge bonding , Ag wire,
- Minimum bonding height

→ **80 µm is possible minimizing stacking height**

IHEP readout chip, VA type

Prototype in Spring 2019

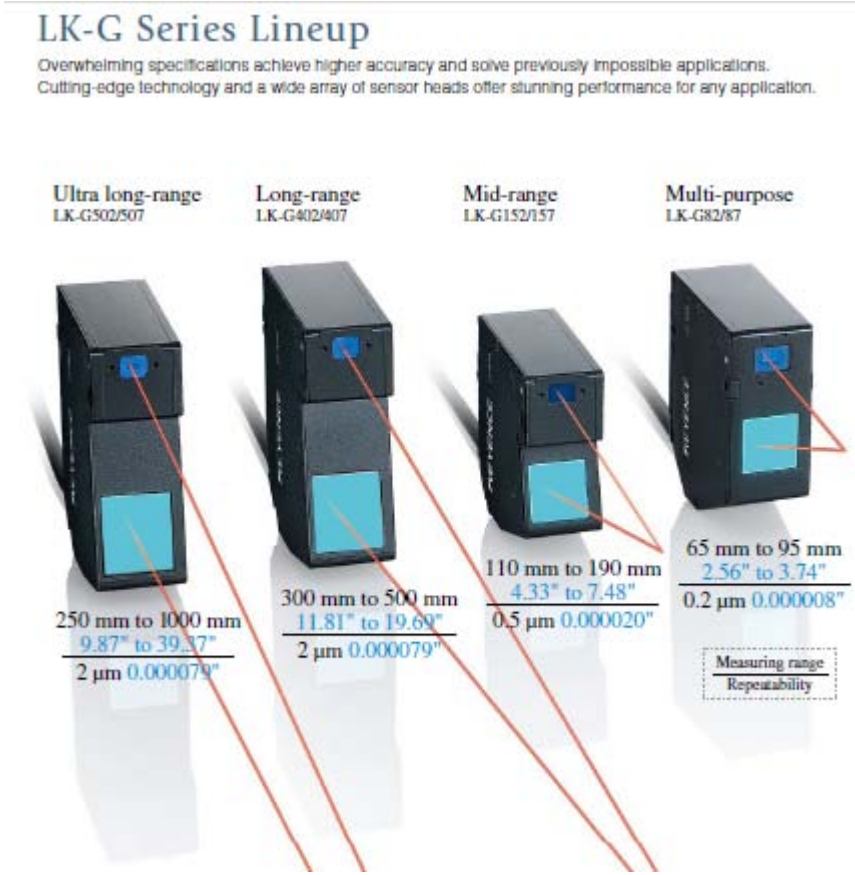


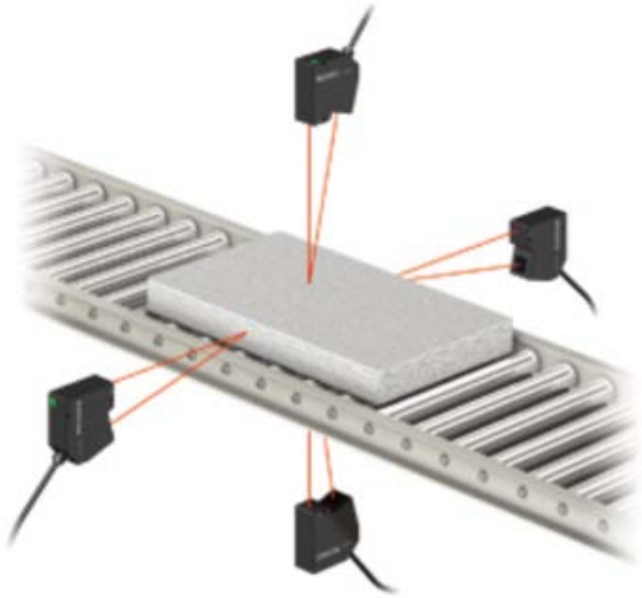
此次打線實驗是以固定直線距離2000um 做弧高控制，弧高可以做到80um，考慮生產良率會控制在150um內。

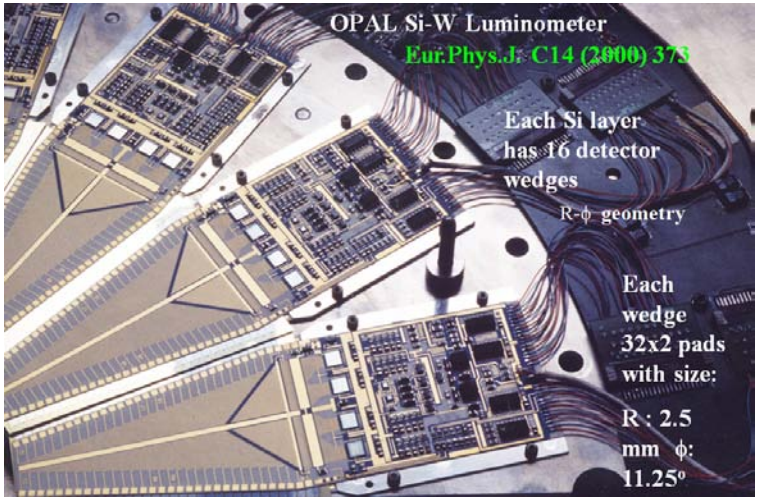
Prototyping a SiW detector

Assembly to 1 µm precision

Keyence Laser Displacement Sensor







Summary

- GEANT simulation needs update of geometry
- Prototyping of Si detector with wide strip detector and IHEP chip
- Dummy assembly testing 1 μm precision