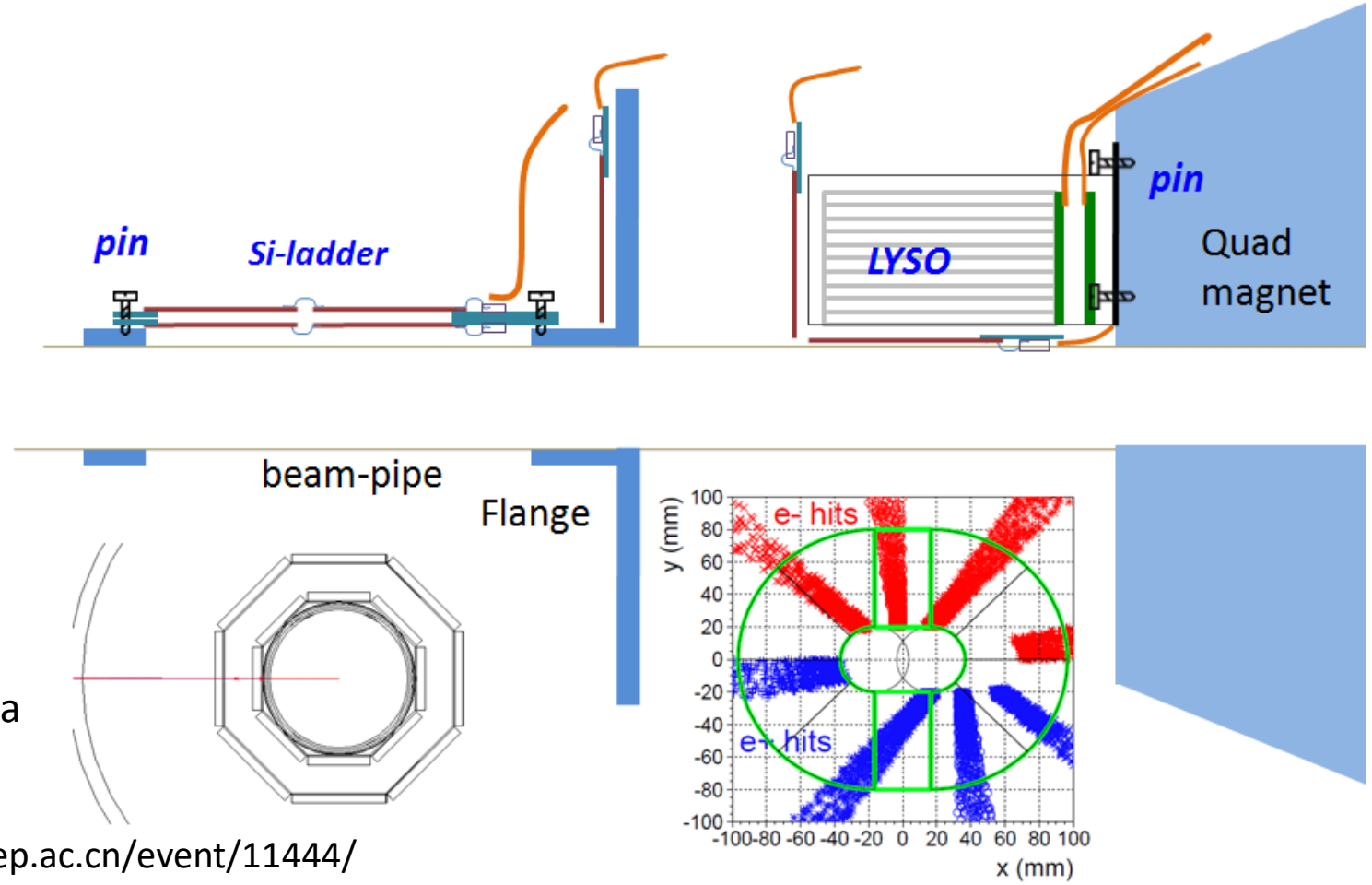
Geometry and Acceptance for CEPC LumiCal



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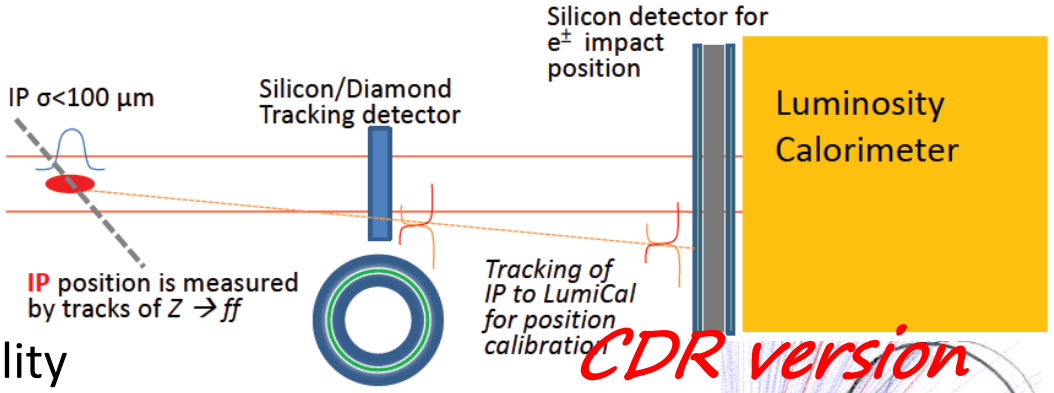
https://indico.ihep.ac.cn/event/11444/

Outline



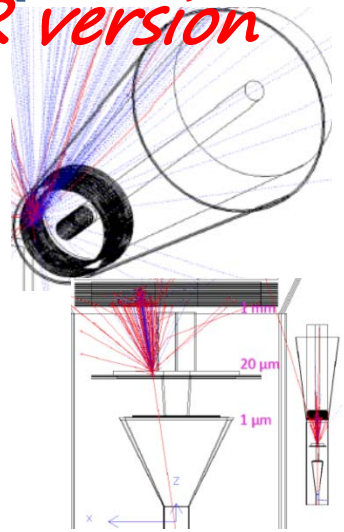
- **CDR LumiCal:**

  a ***Si-W*** stack, w.o. beam-pipe reality

  post-CDR: *beam-pipe geometry & multiple scattering*

  ➔ ***round beampipe Si-ladder + Crystal Calorimeter***

CDR version



- **Bhabha cross section @ Z pole :**

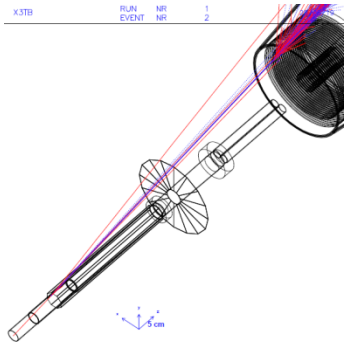
  BHLUMI calculation done

  for θ_{min} = 30 mRad ➔ **σ(Bhabha) = 75 nb**

- **GEANT study for luminosity precision δL/L ~ 10^{-4}**

  multiple scattering passing 1mm Al beampipe

  ➔ **RMS = 50 um** *@Z=0.5m, ϑ = 30 mRad*



- **LumiCal Geometry and Mechanics for δL/L ~ 10^{-4}**

  Si-ladder: detect electron impact position to ***δϑ ~ 1.5 μRad***

  → *Si-wafer surrounding beampipe, do Z-position measurement*

  LYSO Calorimeter:

  → *ID beam-electron/photon*

Luminosity criteria

Luminosity of e^+e^- collisions

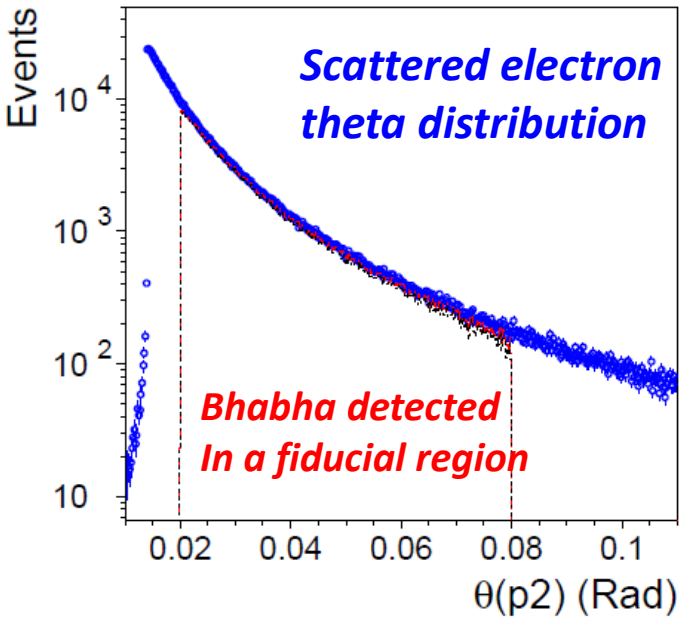
by QED Bhabha elastics scattering
theoretical precision < 0.1 %

$e^+e^- \rightarrow e^+e^-$
crosss section

$$\sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta^2_{min}} - \frac{1}{\theta^2_{max}}\right)$$

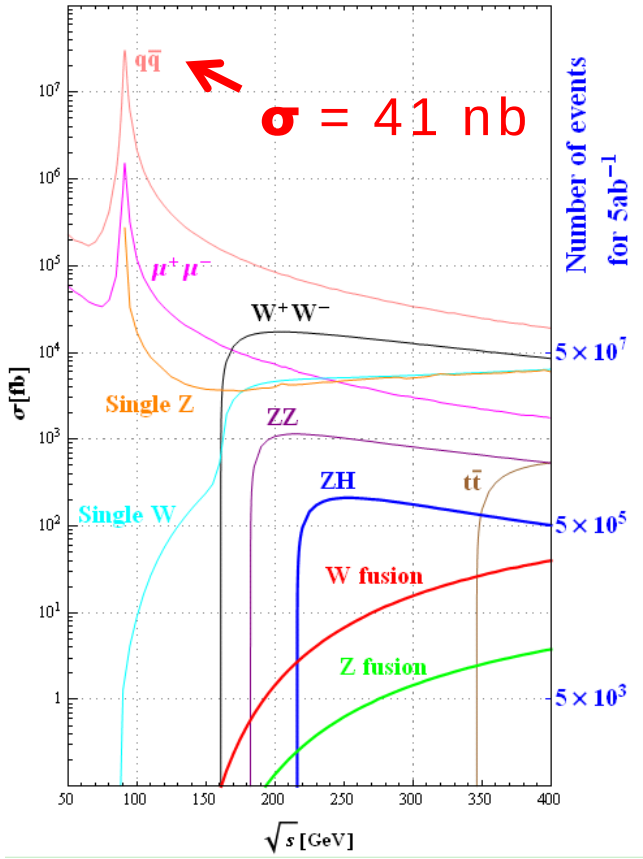
e^+e^- ***collision***
Integrated luminosity

$$\mathcal{L} = \frac{1}{\varepsilon}\frac{N_{acc}}{\sigma^{vis}}$$

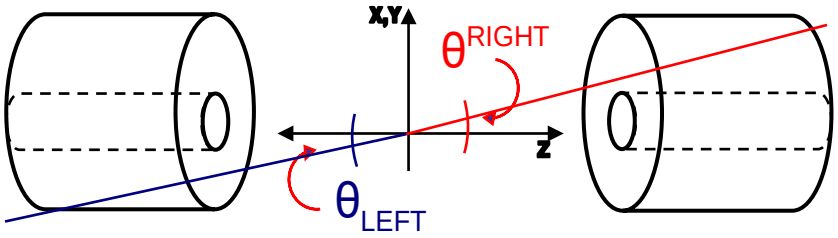


Reference to Z-lineshape

$e^+e^- \rightarrow Z \rightarrow q\bar{q}$



Detecting Bhabha event



Bhabha detection

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

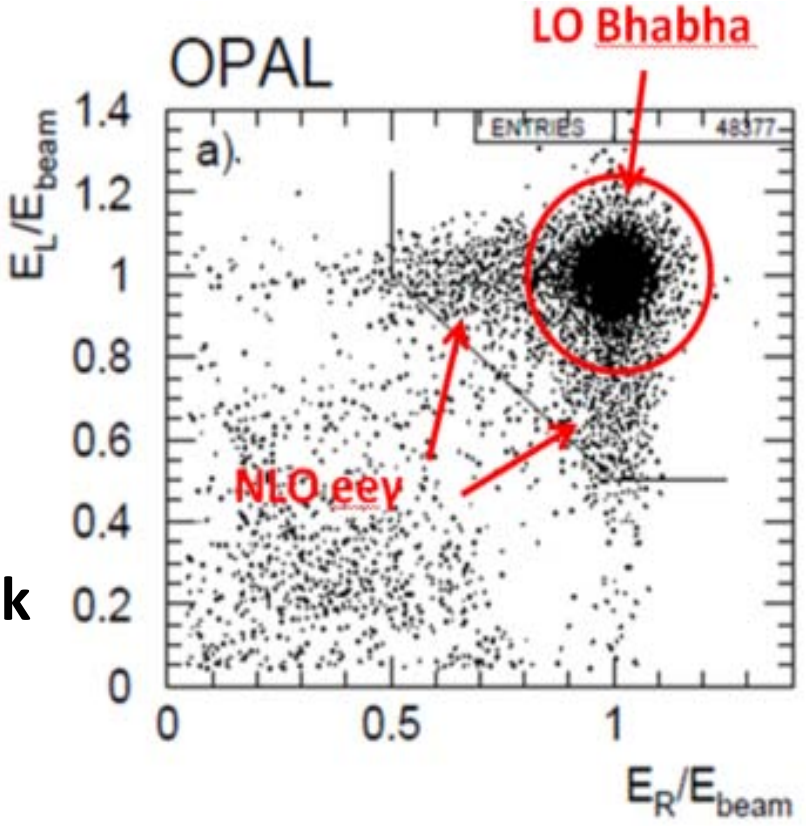
  Event signature

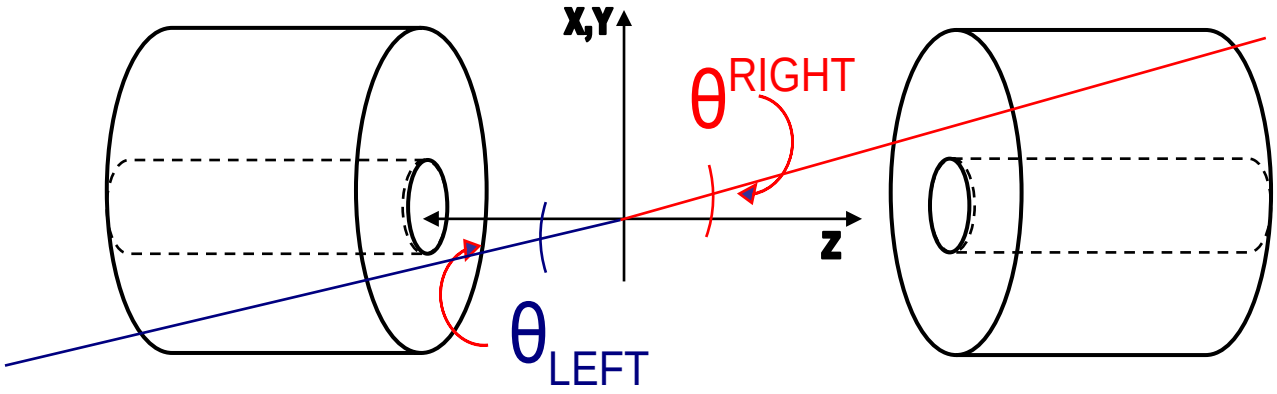
  1. $E(e^{\pm}) = E_{beam}$
  2. e^+ , e^- **Back-to-Back**

- ***NLO*** $e^+e^- \rightarrow e^+e^-\gamma$

  ~1% of total events

  1. e^+ , e^- **approximately Back-to-Back**
  2. **one electron** $E' < E_{beam}$
  3. **e/γ ID, spatial resolution**





Luminosity precision

Dominant systematic error

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

For precision of $\delta L/L < 10^{-3}$

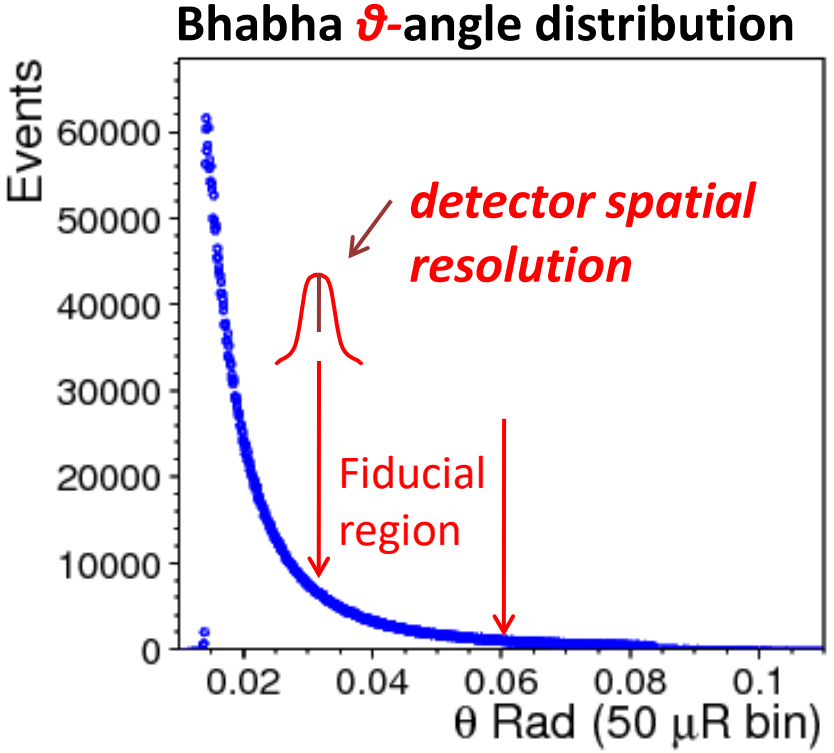
LumiCal @Z= ± **1 m,**

ref: θ_{min} = 30 mRad eq. r = 30 mm

→ $\delta\vartheta$ = 15 µRad eq. dr = 15 µm

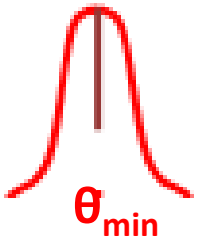
Error due to offset on Z

0.1 mm on z → $dr = \delta R \times \vartheta$ = **3 µm**



LumiCal design goal:

- *Spatial res.: narrow binning*
- *"Standard error of the mean" on* θ_{min}: $\sigma/\sqrt{N} < 15$ µRad



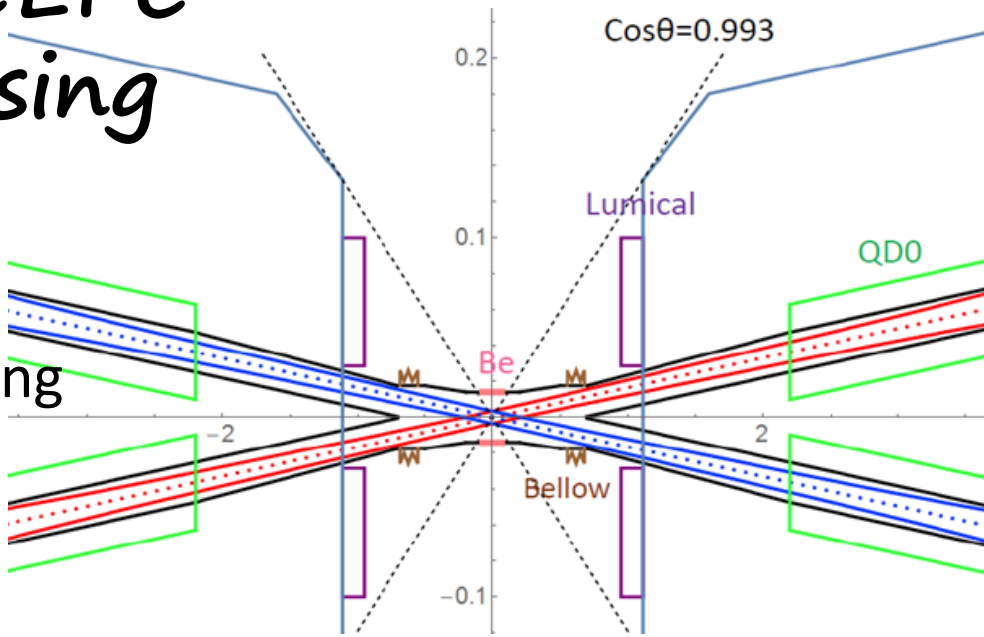
offset on fiducial edge

→ *Systematics to "the* ***mean on*** θ_{min}*"*

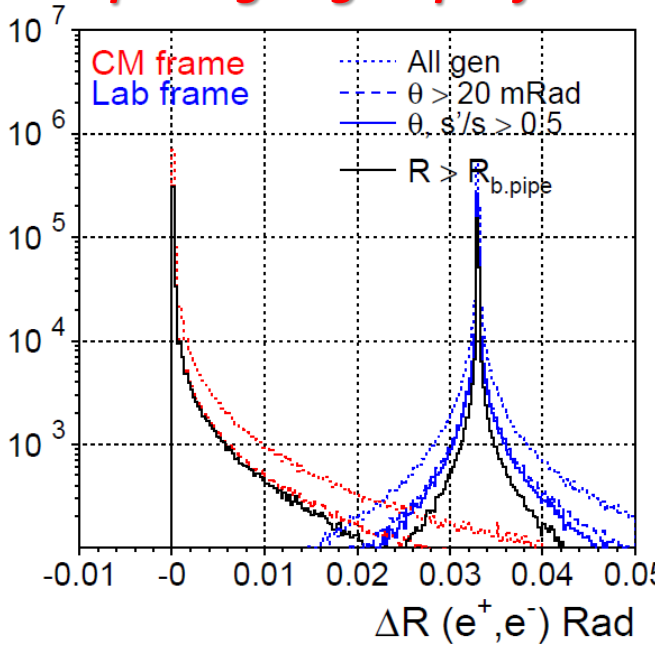
→ ***LUMINOSITY error***

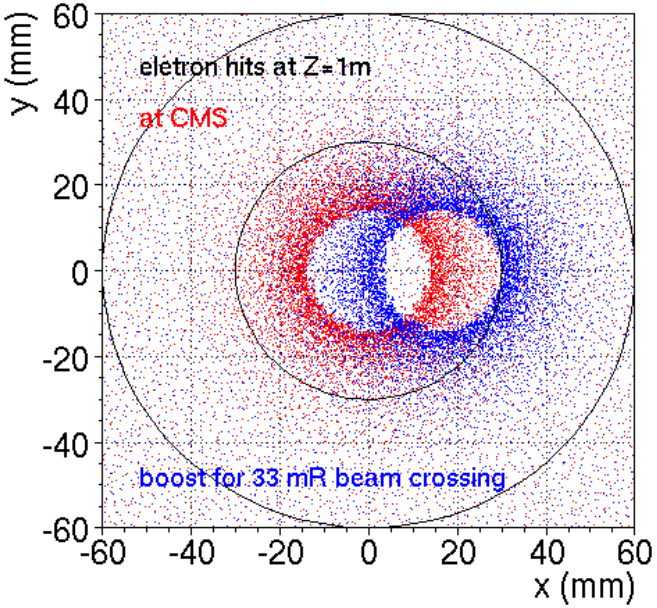
Bhabha boosted by CEPC 33 mRad beam crossing

- **BHlumi QED** calculation for Bhabha e^+e^- *scattering*
- boosted for the 33 beam crossing e^+,e^- shift by ~16.5 mRad to +x direction



Opening angle –pi of the scattered e^+,e^-

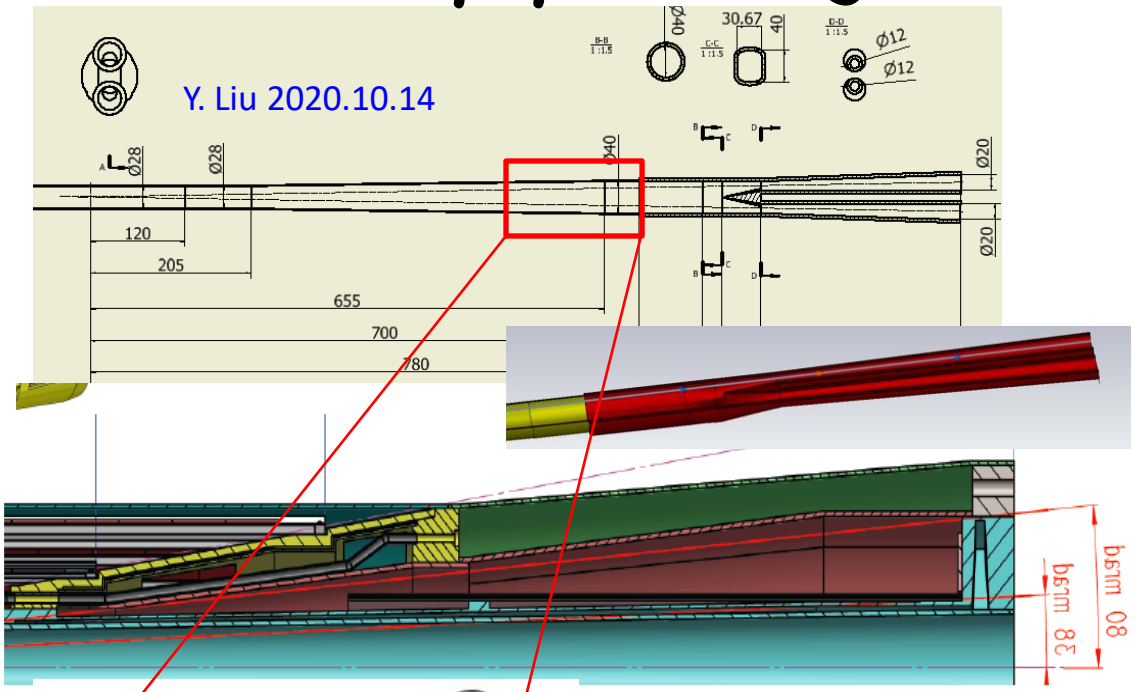




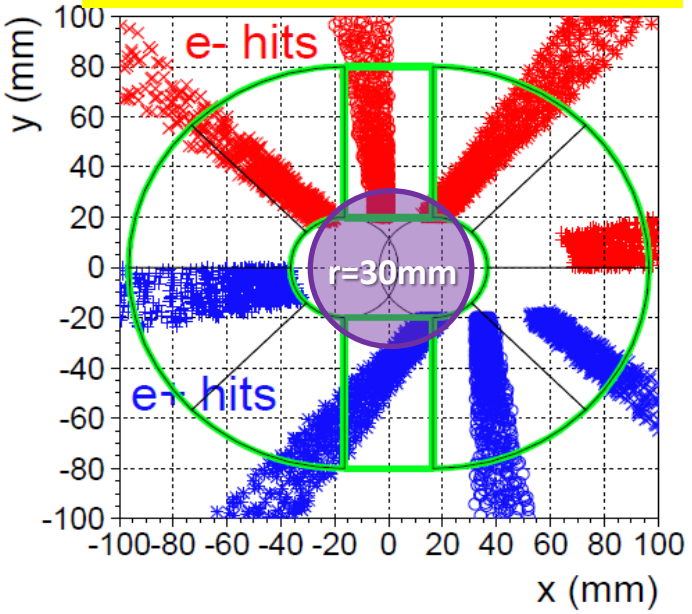
Electrons shifted from CMS to LAB

Bhabha electron x-y distribution at Z=1m

LumiCal acceptance, compare BHlumi with Beampipe design



X-Y hits both e^+,e^- detected at CEPC Z= ± 1 m



BHLUMI estimate boosted electron distribution **for a round beampipe ϑ_{min} = 30 mRad**

CMS θ range: 10 ~ 80 mRad		LAB detecting *one* electron	LAB detecting *both* electrons
Nevents	457232	102535	29194
Xsec (nb)	1168.3	262 nb	74.6 nb

*latest beampipe before Flange @Z=655 mm, acceptance suggested for θ_{min} >38 mRad ➔ *LumiCal Acc < 40 nb*

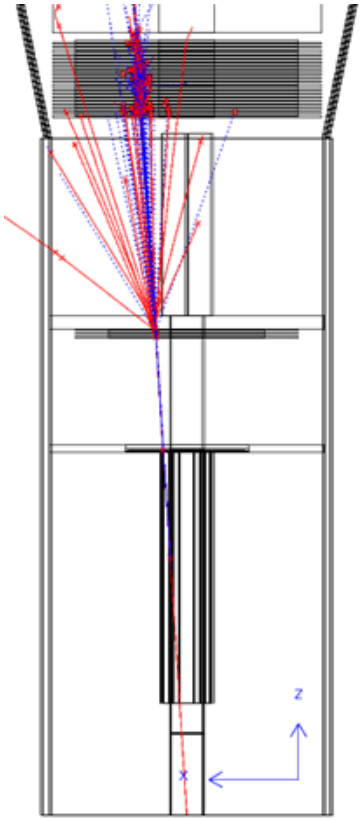
GEANT, multiple scattering off beampipe

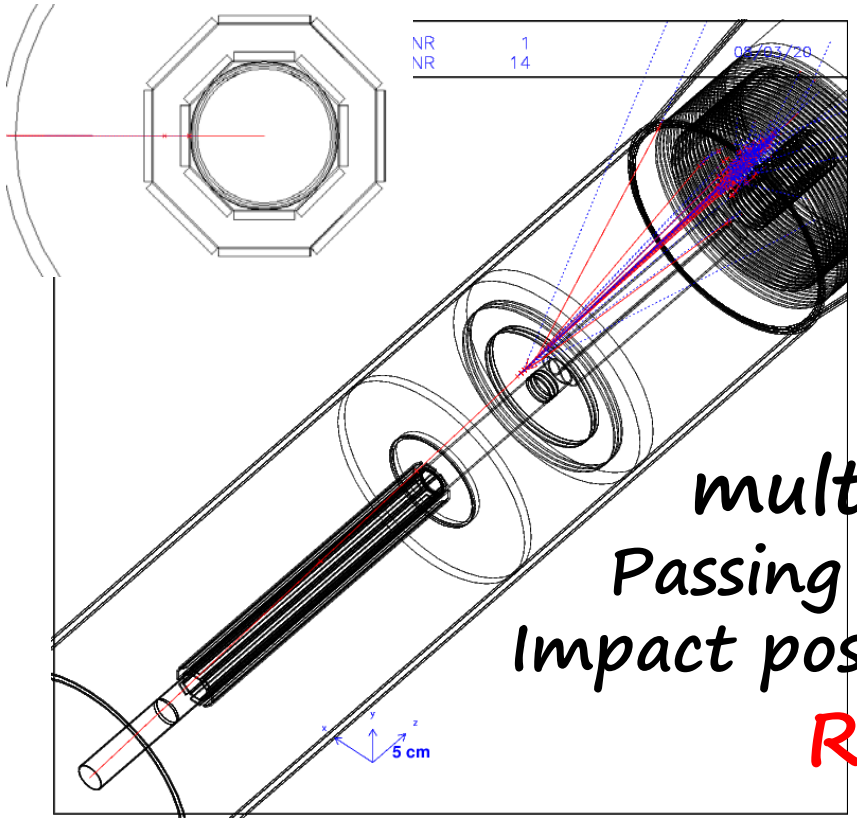
Si-ladders surrounding beampipe

➔ minimal smearing by multiple scattering/shower

Electron traversing 1 mm thick Al beampipe

@30 mRad, Z = 0.5 m, dZ traversing beampipe = **33 mm**

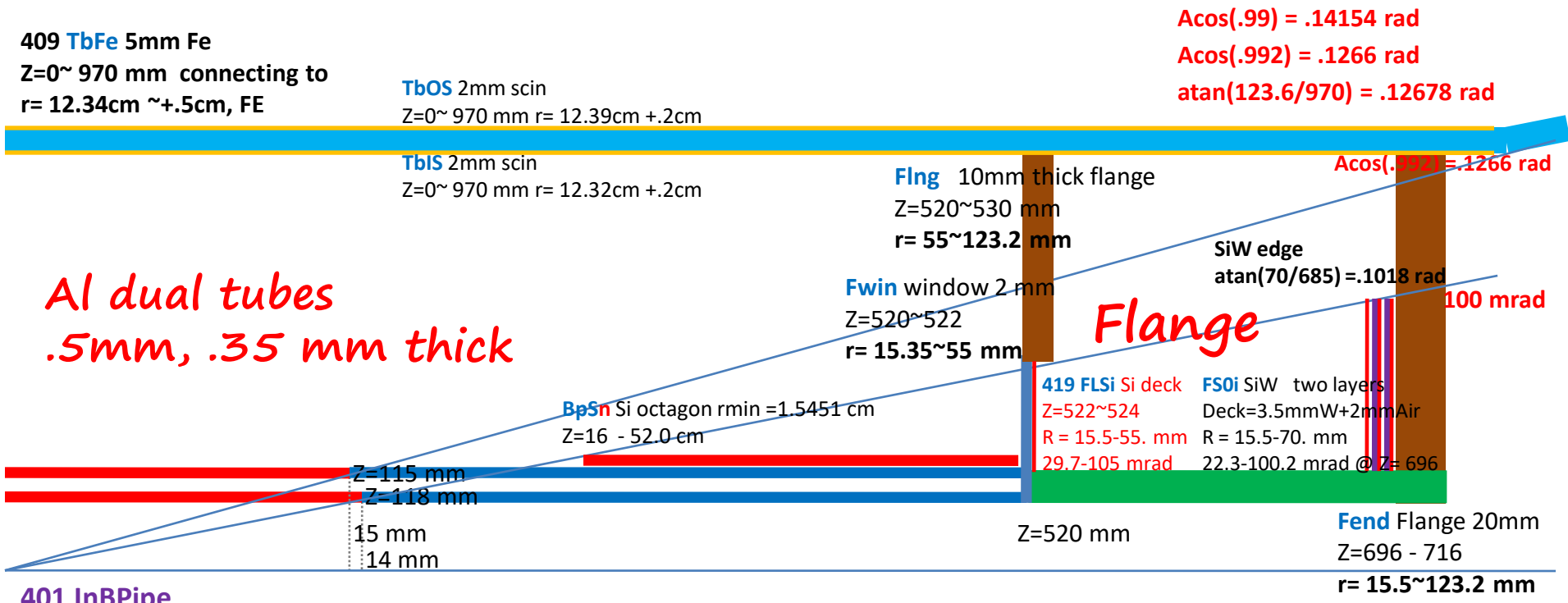




GEANT
multiple scattering
Passing 1 mm beampipe
Impact position on Si-layer
RMS = 50 μm

GEANT TUBE beam-pipe, Si-ladders

acos(.99) = 141.54 mRad @Z=118 → r= 16.81 (=tanQ*118)
acos(.992)= 126.58 mRad @Z=118 → r= 15.02 mm
Q= 100mRad @Z=118 → r= 11.84 mm @Z=153 → r=15.35 mm



401 InBPipe

InBP Inner Be pipe
Z=0~118 mm,
inner diameter 28 mm 0.5mm thick

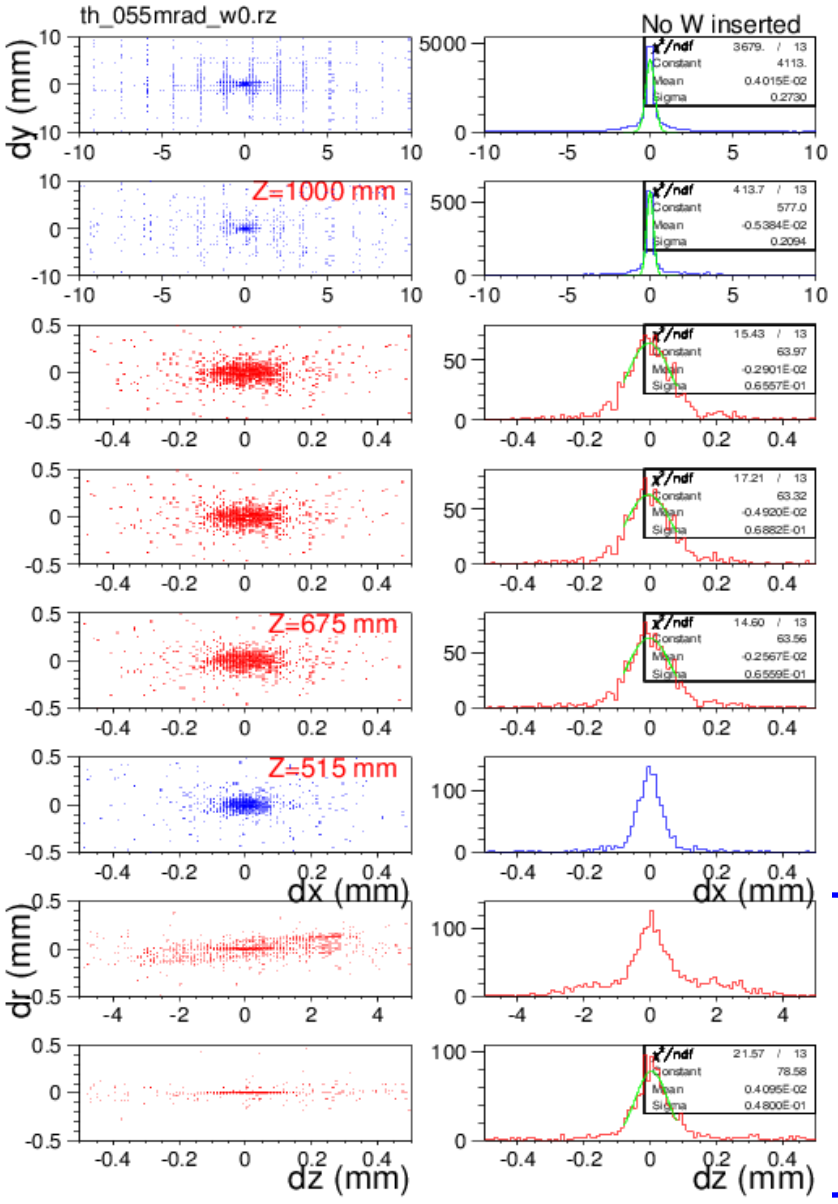
InAl Inner Al pipe
Z=118~500 mm,
inner diameter 28 mm 0.5mm thick

Fpip flange pipe 1.5 mm thick
Z= 522-716 mm
at Z=512 r= 14 – 15.5 mm

OuBP outer Be pipe
Z=0~115 mm
inner radius 28/2+1 mm 0.35mm thick

OuAl outer Al pipe
Z=0~115 mm
inner r=28/2+1 mm, 0.35 mm thick

Position(Hits) – Electron shower



Piled up of 50 GeV electron shower hits

Front 2 Si-layers of Q-pole LumiCal

Pileup of shower ~1 mm resolution

Three Si layers at Z>670 mm

NO Tungsten layers σ= 65 um

1st Si layer behind flange at Z=515 mm

Octagon Si-ladders surrounding beampipe

1st layer σ= 50 um

Options of LumiCal assembly

- ***2D Si-ladder*** assembled on CNC table

  z-strips for theta position: ***<200*** µm pitch for resolution <25 µm

  phi-strips: ~ 1 mm pitch to correct boosted direction

  alignment **pin** to beampipe support➔ precision **~5 µm**

  CNC survey of Si strip position **~ 3 µm**

*use fine-pitch Si-strip to differentiate **Mult.Scatt.** distribution (**50 µm** width) for event counting over ϑ_{min} to **25 µm** precison*

- ***Bhabha electron resolution:***

  @fiducial edge, assuming θ_{min} = 30 mRad

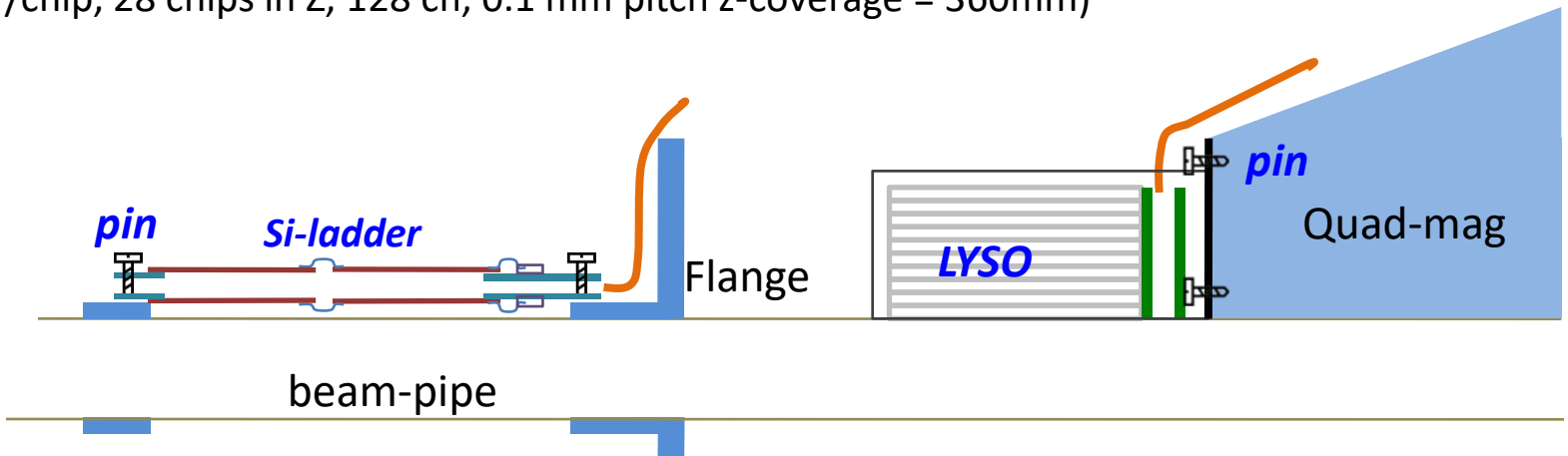
  $\delta L/L < 10^{-4} \rightarrow \delta\vartheta = 1.5\ \mu Rad$

  @ Z= 0.5 m, corresponding to dr= 0.75 µm; dz = dr/tan(.03)= **25 µm**

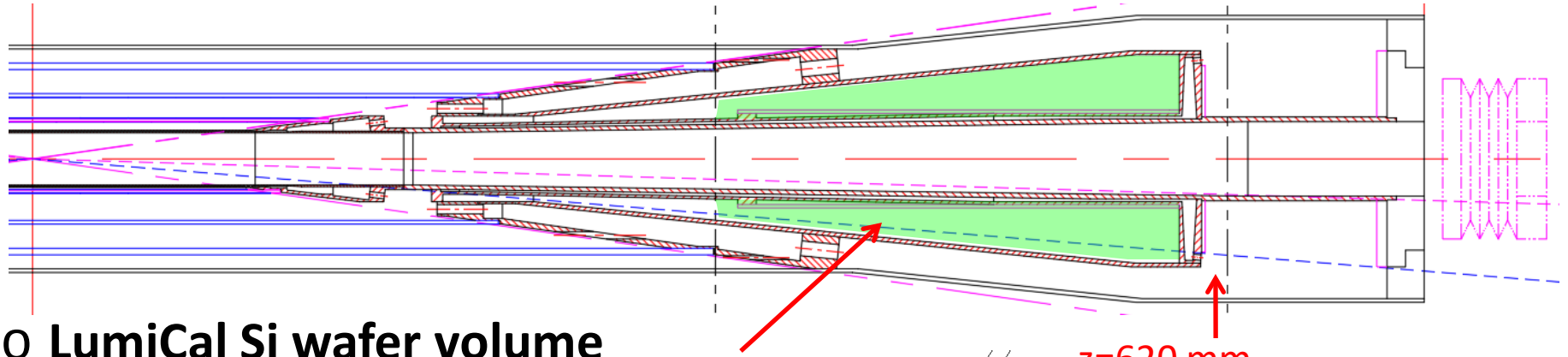
- ***Heat dissipation:***

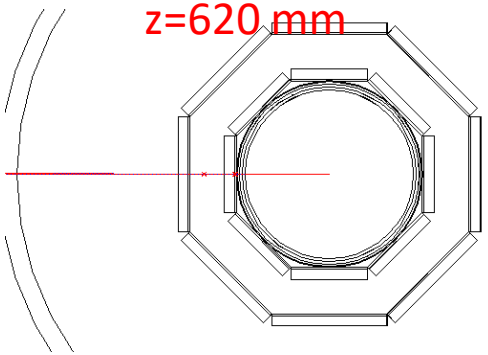
  8 pairs of z-phi ladders, 30 chips ➔ **100 W /per z-side**

  (APV25 0.4 W/chip, 28 chips in Z, 128 ch, 0.1 mm pitch z-coverage = 360mm)



LumiCal Si-wafer option



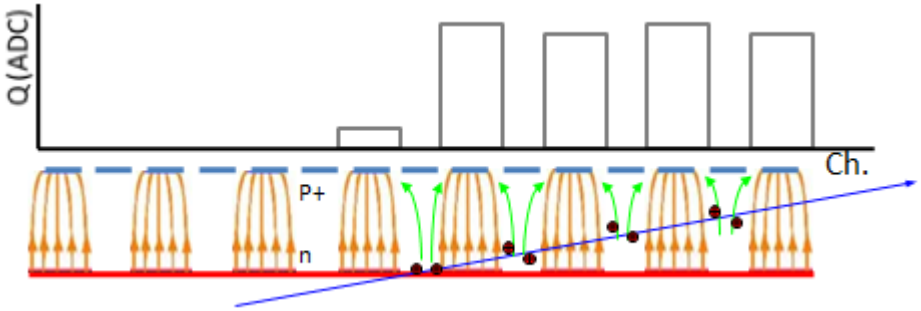


- **LumiCal Si wafer volume**
  GEANT for round beampipe ***φ = 28 mm***
  θ = 30 mRad @ z=500 mm
  Multi. Scattering at Si wafer: **RMS = 50 µm**

***Assuming Si strip 300 µm thick, pitch = 100* µm,**
resolution by the fraction of entrance strip (low z)

➔ ***fire 100 strips @ 30 mRad***

➔ *rather extreme for Si strip*
resolution by charge sharing
at the edge strips



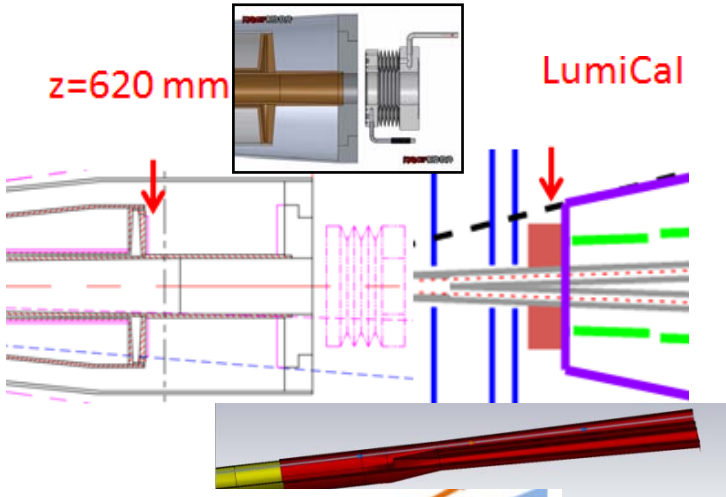
LumiCal Calo options

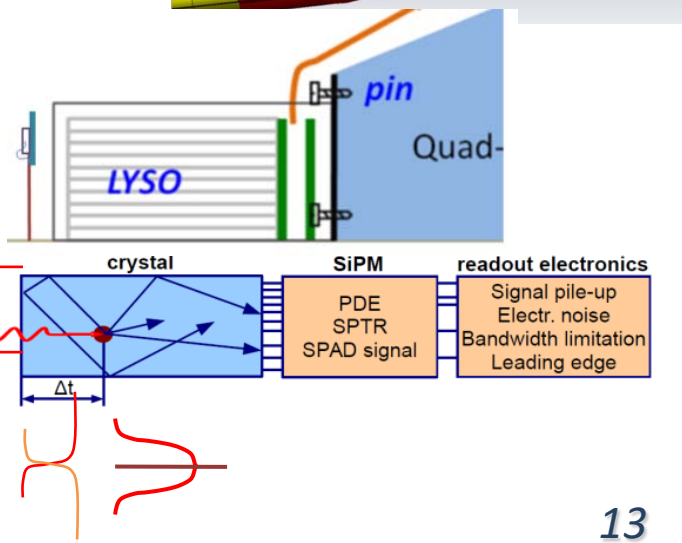
- **Calorimeter option:** ***LYSO + SiPM***
  to minimize space for electronics
- **Si-layers in flange/Calo front**
  as preshower layers for e/γ ID, NLO photon
- **Calo Assembly:**
  LYSO in 2x2 cm^2 bars
  ~50 kg ring, mounted on Magnet
  fabrication may be better than **10 *μm***

Upstream to Calo:

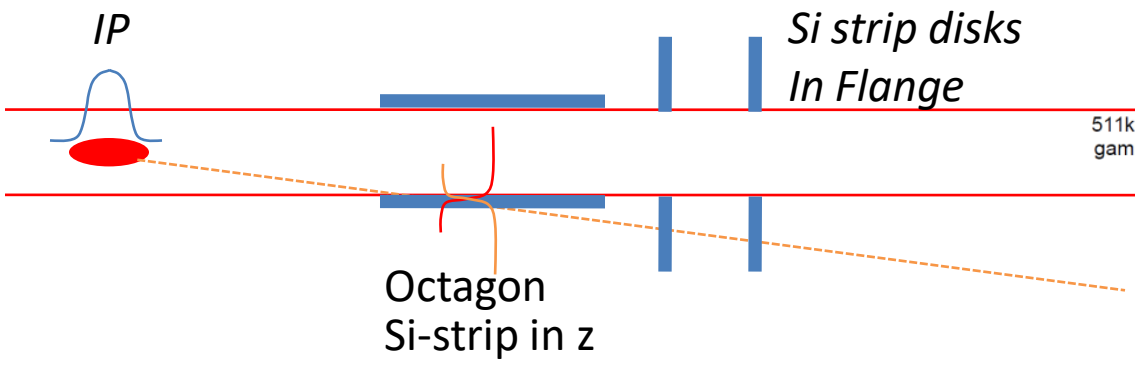
beam-pipe, flange, possibly ***~5 X_0***

shower center ~1 mm precision





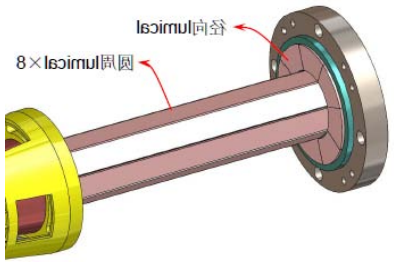
More detailed works needed !!



Summary

- ***Bhabha detection*** studied for luminosity ***δL/L ~ 10^{-4}***
  optimizing acceptance for Z(qq) pole cross section

- Detecting electron, resolution at ϑ_{min} edge :
  δL/L ~ 10^{-4} → $\sigma_{\vartheta min}$ = 1.5 μRad



  Si-ladders surrounding beam-pipe:
  electron Z position (@30mRad), ***$\sigma_{\vartheta min}$ → σ_Z = 25 μm***
  measuring Bhabha electrons
  with impact position smeared by Multiple-Scattering

- ***Calo (LYSO+SiPM)*** for e/γ identification
  further details to be studied !