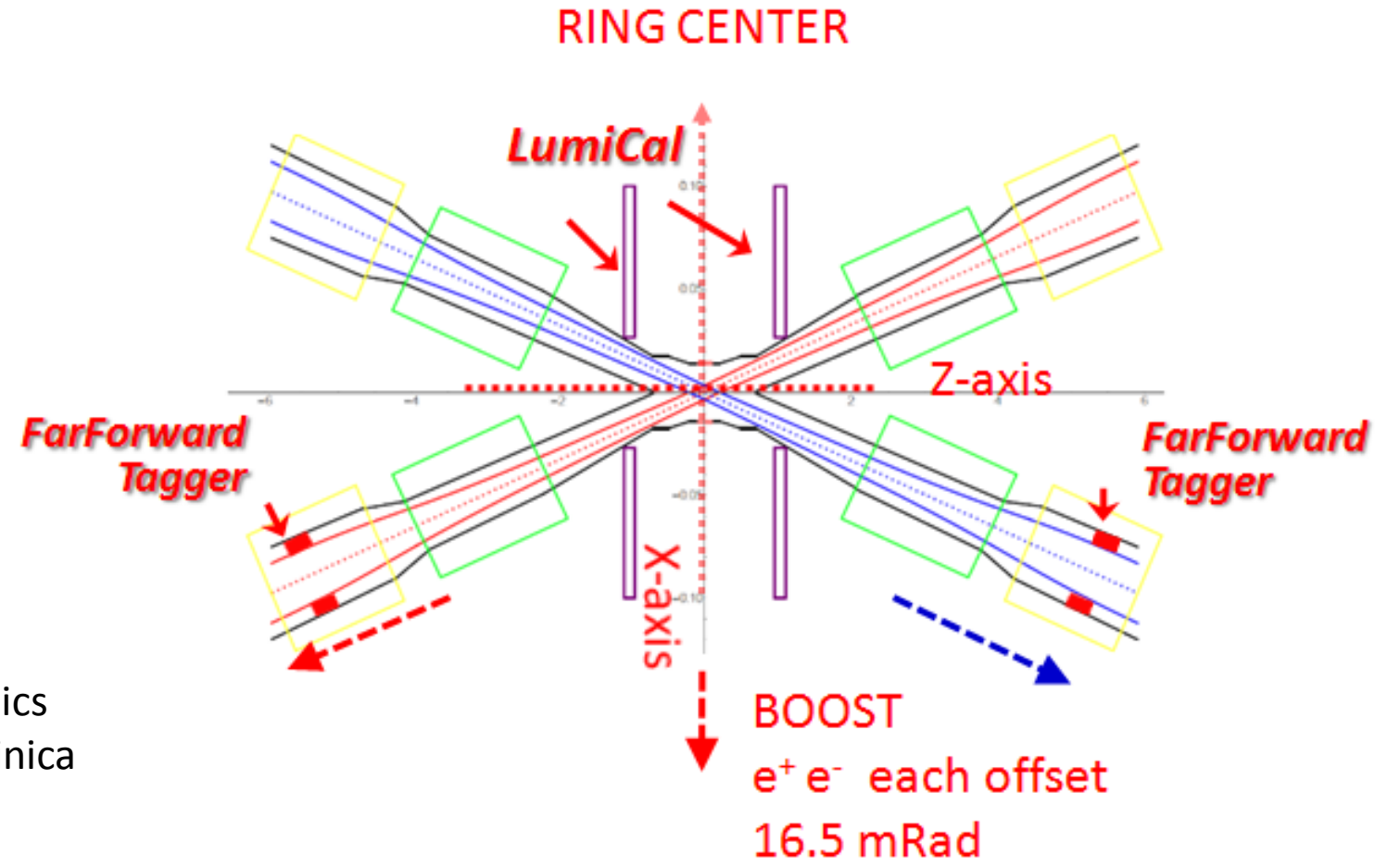
Geometry and cooling for the Lumi detector in MDI



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https://indico.ihep.ac.cn/event/12324/session/1/contribution/3

Progress and perspectives

- **Bhabha cross section for Z pole :**
  reference to Z-pole, theoretical **BHLUMI** calculation done
  beam-pipe **ϕ ~ 28 mm**
  → Bhabha θ_{min} < 30 mRad → σ(Bhabha) > 50 nb

- **GEANT study for luminosity $\delta L/L \sim 10^{-4}$**
  beampipe material → multiple scattering, EM shower
  beampipe shape, detector position → spatial resolution

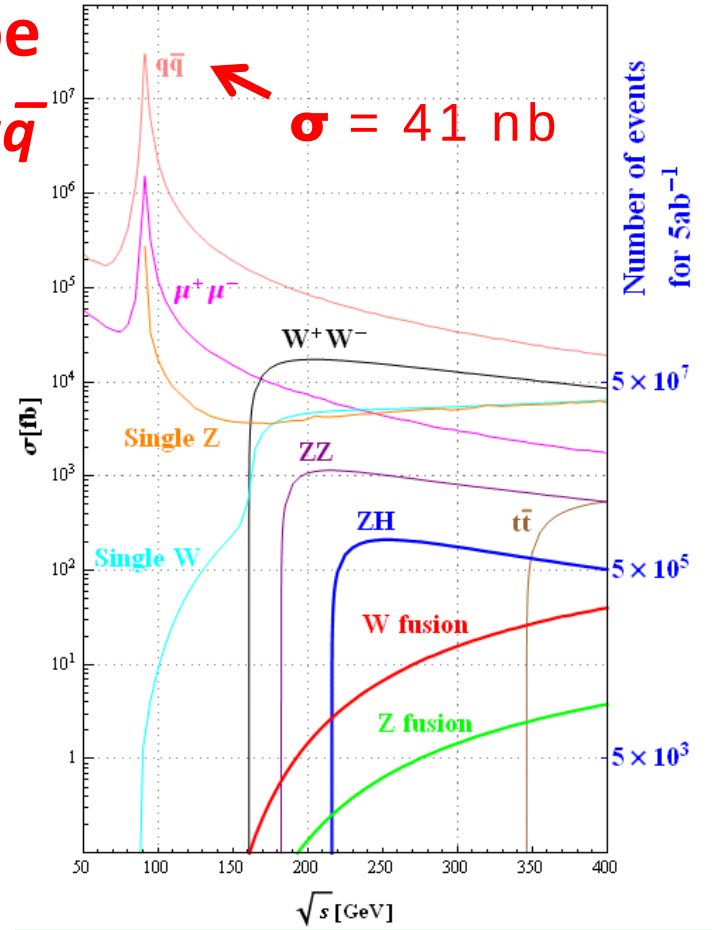
- **LumiCal Geometry and Mechanics**
  Si-ladder for electron ***$\delta\vartheta$ ~ 1.5 μRad*** resolution
  → Si-wafer surrounding beampipe, Z-position measurement
  LYSO Calorimeter tagging beam scattered electron/photon
  → ***Flange details and geom NOT yet optimized***

➔ R&D migrating to hardware and electronics

Luminosity measurement

- ***Reference to Z-lineshape***

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

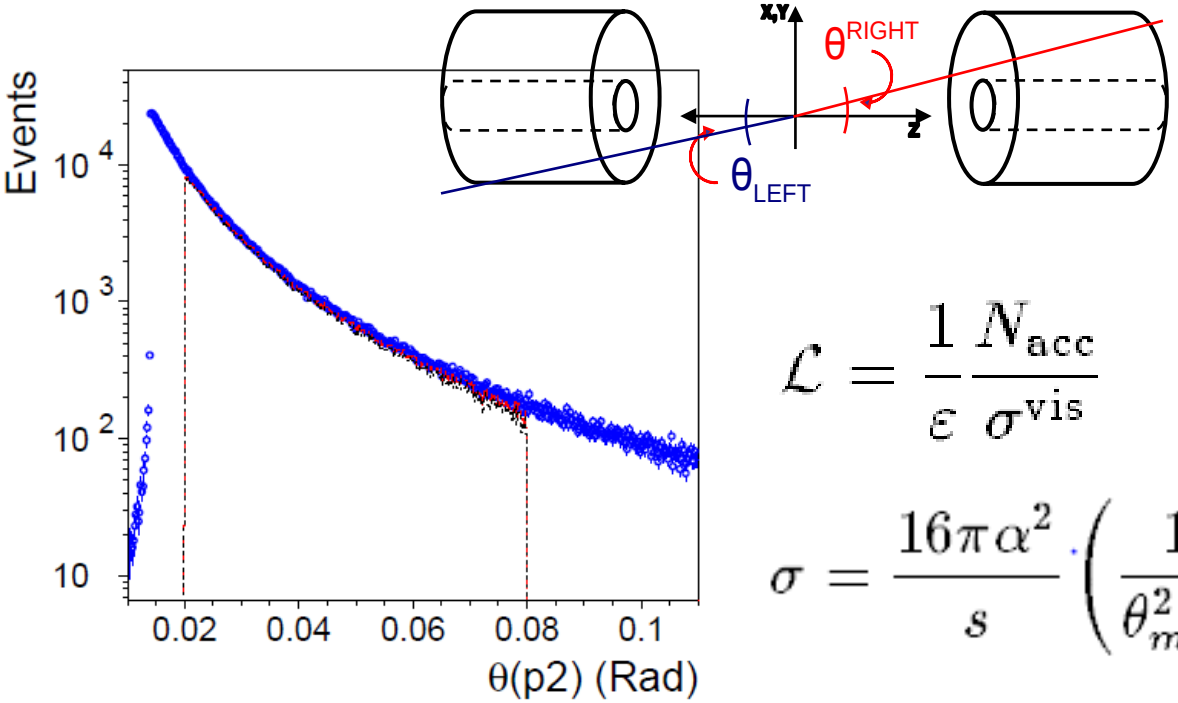


- **Luminosity of e^+e^- collisions**

  reference by QED Bhabha elastics scattering

  theoretical precision < 0.1 %

  $e^+e^- \rightarrow e^+e^-$



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

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

Bhabha detection

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

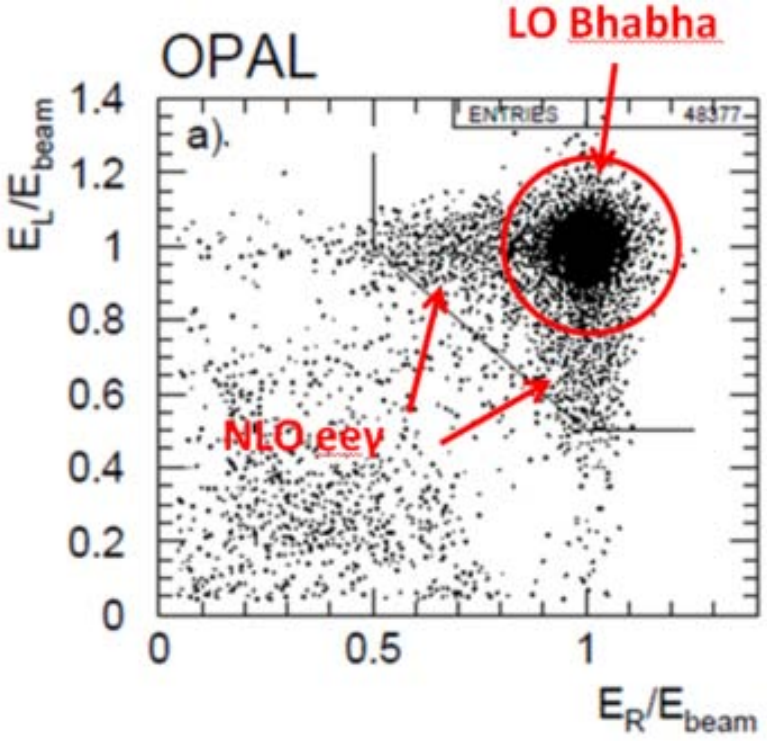
  Event signature

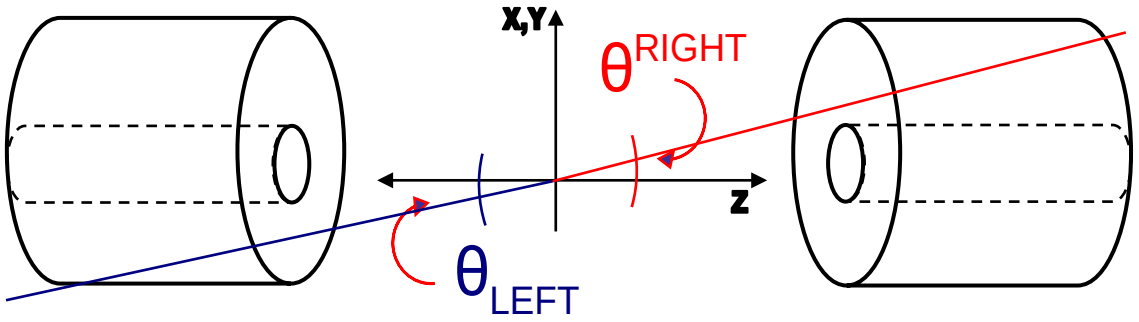
  1. $E(e^{\pm}) = E_{beam}$
  2. e^+, e^- Back-to-Back

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

  ~1% events

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





$$\Delta\theta \equiv \theta_{RIGHT} - \theta_{LEFT}$$

Luminosity precision

Dominant systematic error

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

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

LumiCal at **z = ±1 m,**

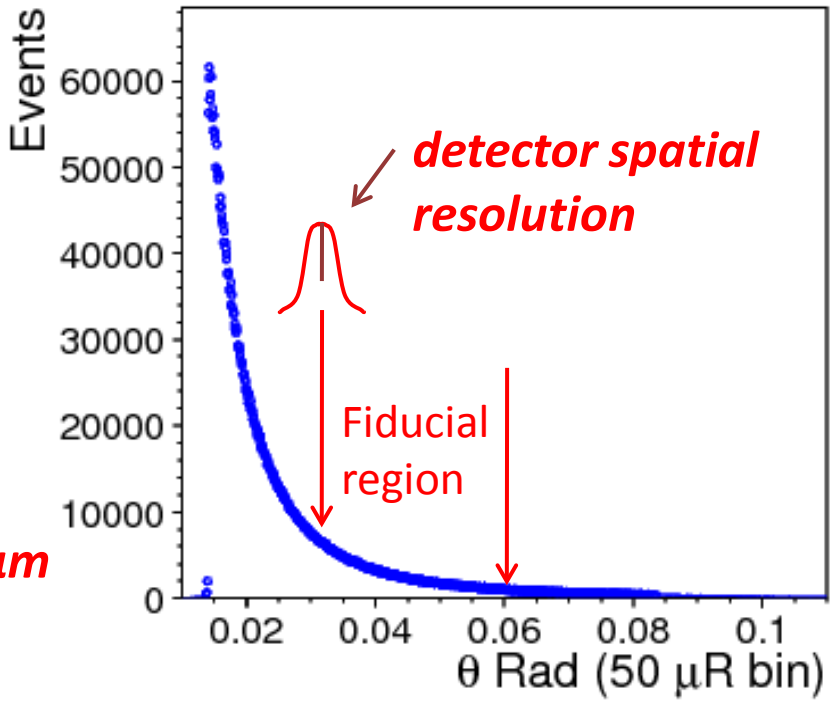
ref: θ_{min} = 30 mRad eq. r = 30 mm

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

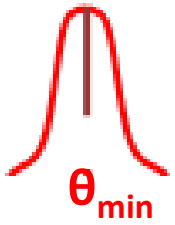
Error due to offset on Z

assum. *0.1 mm on z* → $dr = \delta R x \vartheta$ = **3 µm**

Bhabha ϑ-angle distribution



LumiCal design goal:



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

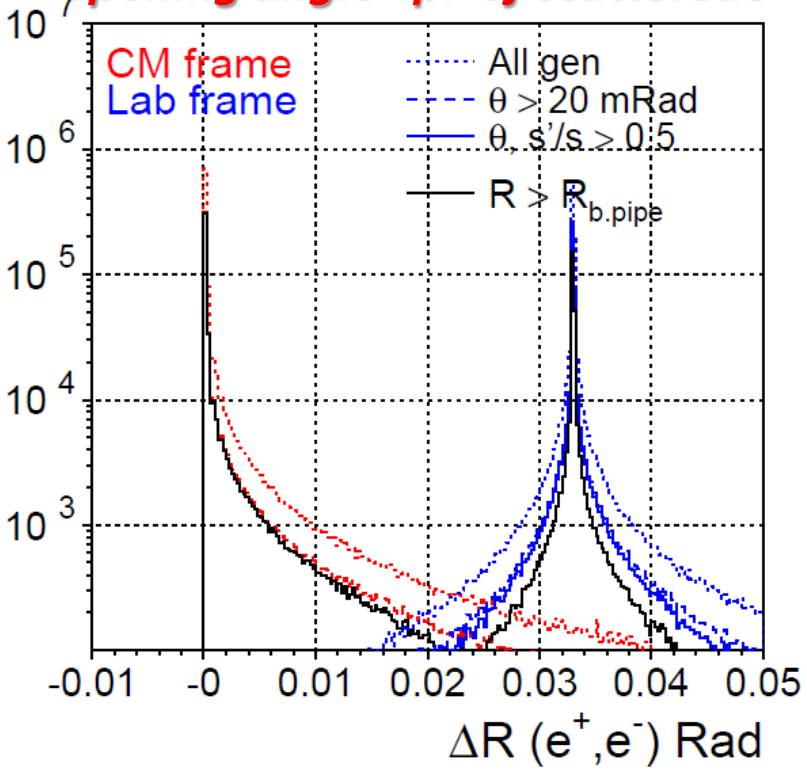
offset of fiducial edge to "the ***mean on*** θ_{min}*"*

→ ***LUMINOSITY error***

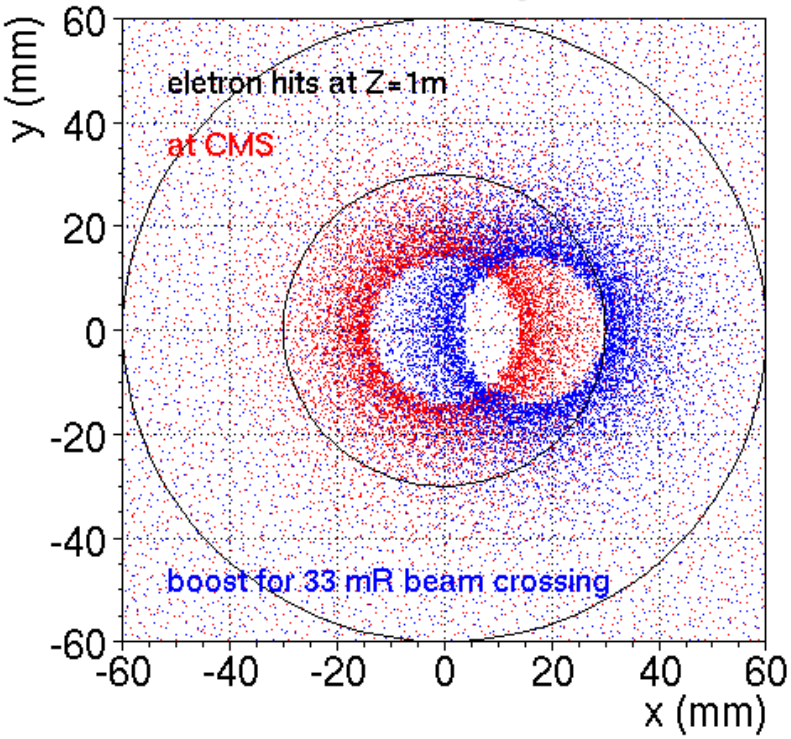
Bhabha back-to-back boosted by 33 mRad beam crossing

- Bhlumi electrons boosted for the 33 beam crossing by ~16.5 mRad to +x direction
- Compared for Bhabha selection conditions

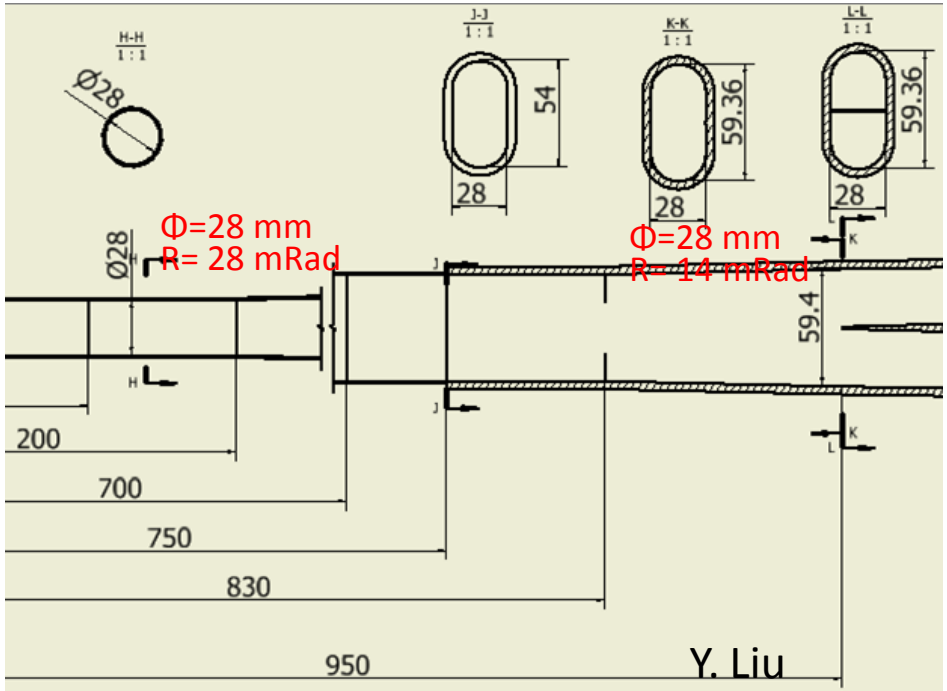
Opening angle –pi of scatterede+ e-



Bhabha at detector plane Z=1m

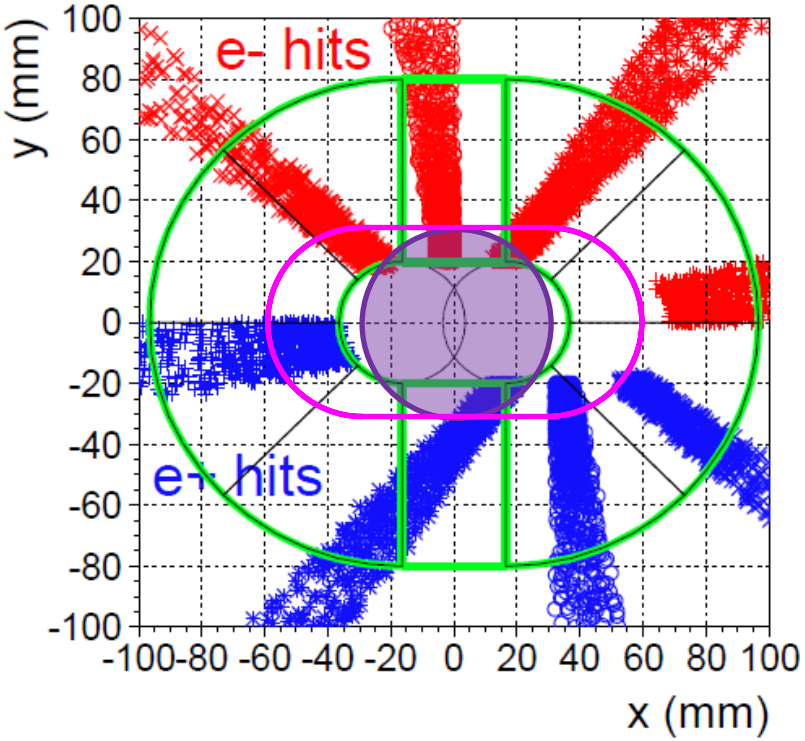


Bhabha cross section



(BHLUMI, boosted for 33 mRad beam crossing)

X-Y hits at Z= ± 1 m



beampipe, r= 30 mRad (vertical) → σ(Bhabha) ≳ 50 nb

(r=30mm **@z=1m**)

CMS 10 ~ 80 mRad		LAB detect ***ONE*** electron		LAB detect ***both*** electrons	
BARE1		off beampipe full phi coverage	off beampipe cut off ±30mm	off beampipe full phi coverage	off beampipe cut off ±30 mm
Nevents	457232	102535	20277	29194	19216
Xsec (nb)	1168.3	**262.0**	**51.81**	**74.60**	**49.10**

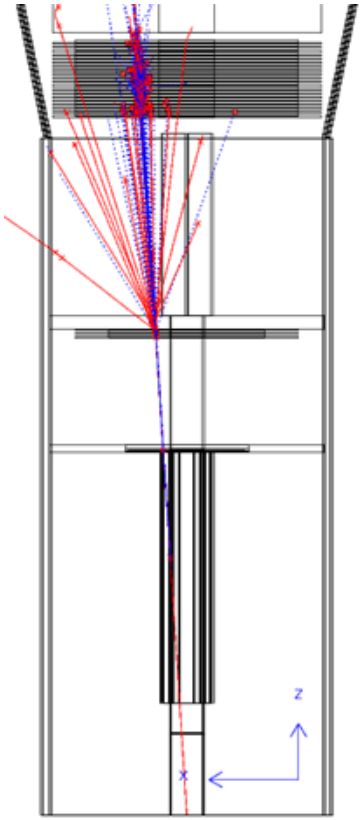
Si octagon wafers surrounding beampipe

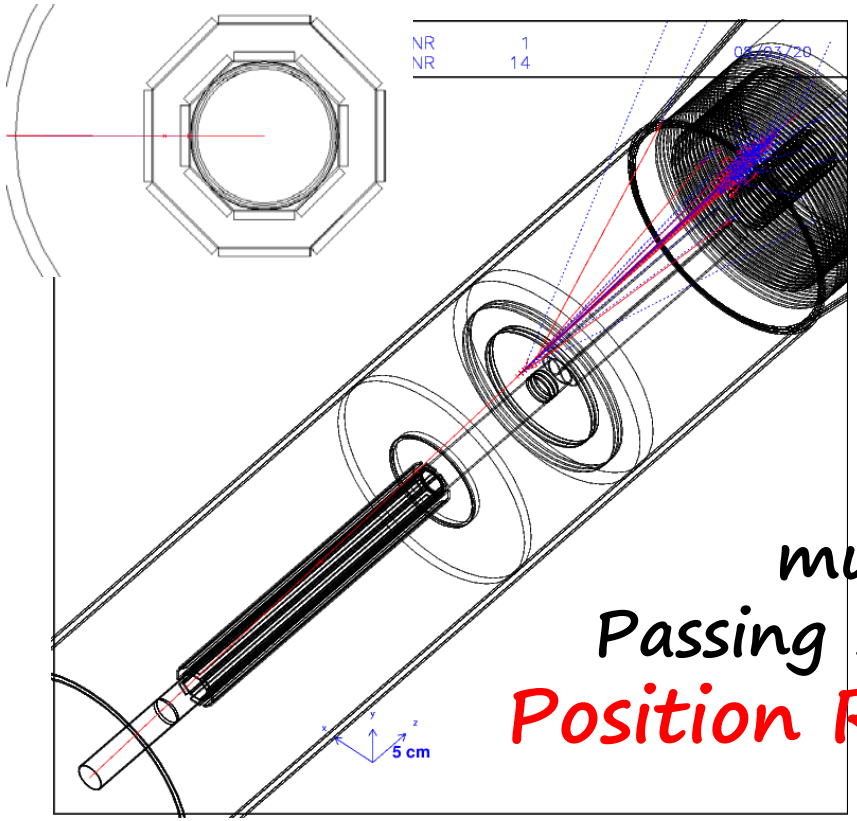
Si-ladders surrounding the beampipe

➔ minimized smearing by multiple scattering/shower

Electron traversing 1 mm thick Al beampipe

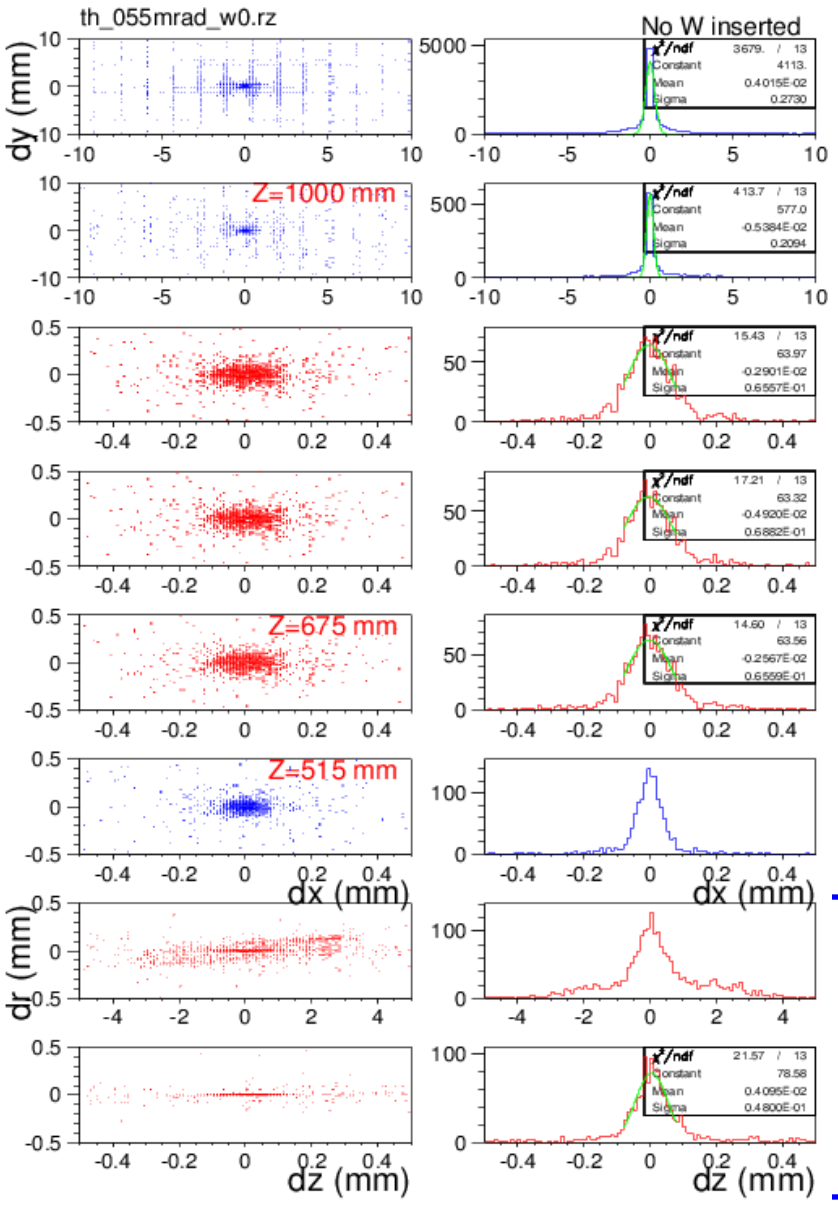
@30 mRad, Z = 0.5 m, dZ traversing beampipe = **33 mm**





GEANT
multiple scattering
Passing 1 mm beampipe
Position RMS = 50 μm

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

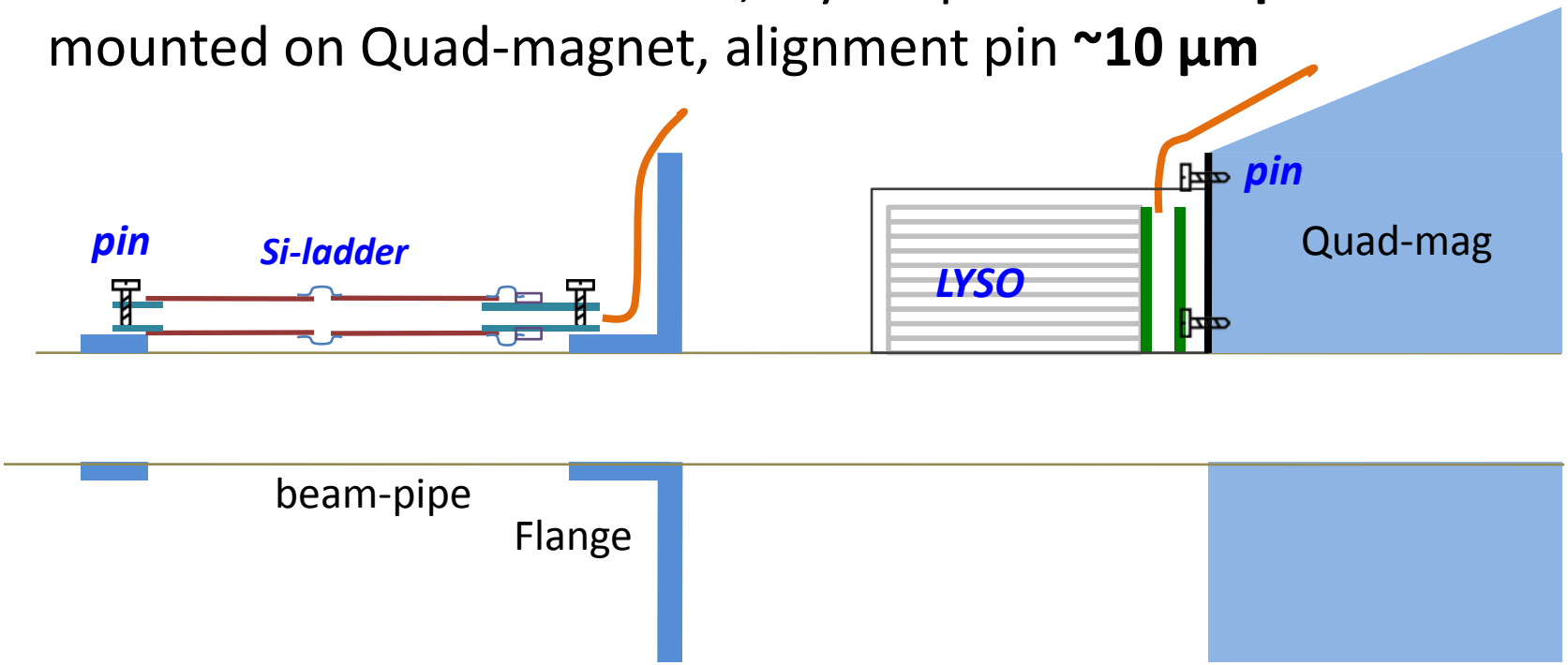
1st Si layer behind flange at Z=515 mm

Octagon Si-ladders surrounding beampipe

1st layer σ= 50 um

LumiCal assembly

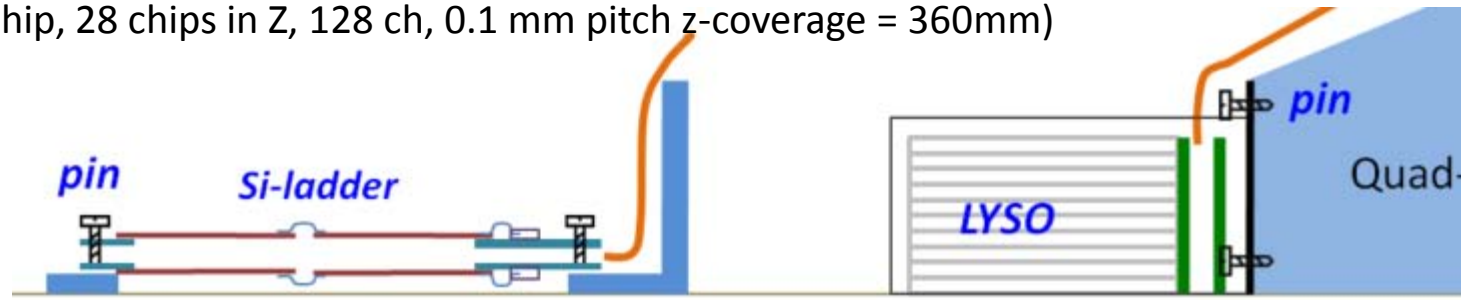
- ***Si-ladder*** assembled on CNC table
  alignment **pin/screw** to beam-pipe support
  pin position precision **~5 µm**
  CNC survey of Si strip position **~ 3 µm**
  readout-hybrid heat dissipation → flange water cooling
- ***LYSO + SiPM*** calorimeter
  assembled in Steel container, crystal position **~10 µm**
  mounted on Quad-magnet, alignment pin **~10 µm**



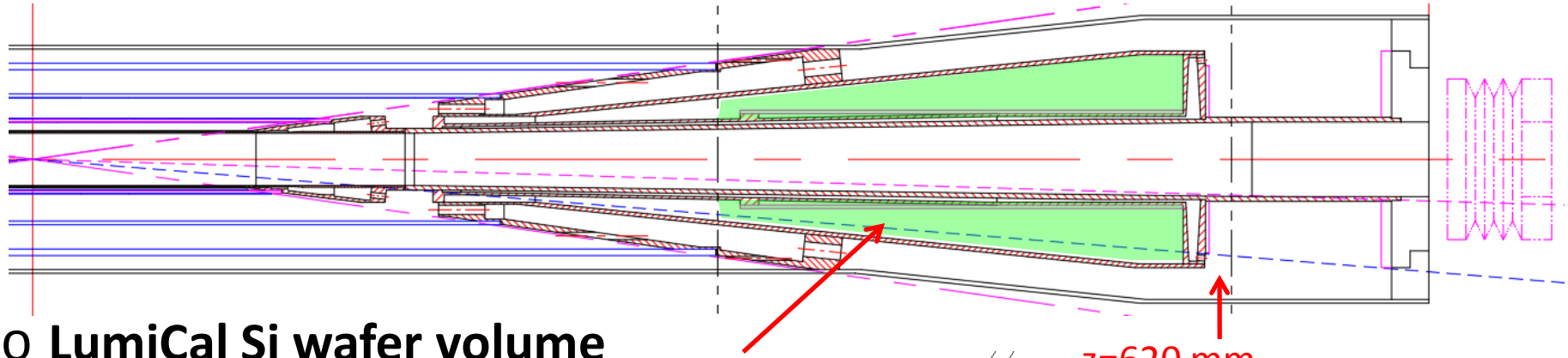
LumiCal Si-ladders: impact position

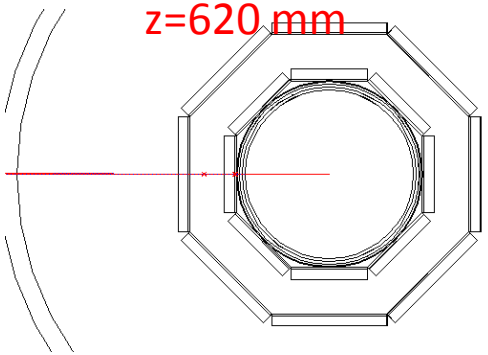
- ***Bhabha electron theta resolution:***
  $\delta L/L < 10^{-4}$ → $\delta\vartheta = 1.5\ \mu Rad$ @fiducial edge θ_{min} = 30 mRad
  @ Z= 0.5m, dr= 0.75 µm; dz=dr/tan(.03)= **25 µm**
- ***Si-ladders in z-phi 2-D assembly:***
  z-strips for theta impact position: <200 µm pitch for resolution <25 µm
  phi-strips: ~ 1 mm pitch to correct boosted direction
- ***Assembly precision:***
  wafer on ladder module: CNC table glue/survey to ***3 µm***
  ladder on beam-pipe support: alignment pin to ***10 µm*** in Z
  Beam-pipe over 1 m thermal/humidity → deviation **~5 *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



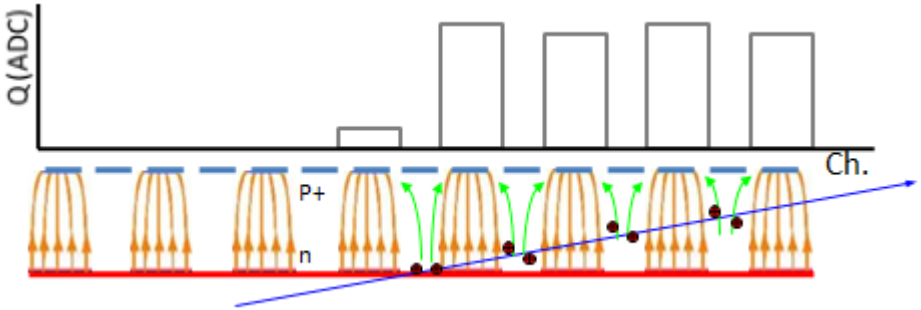


- **LumiCal Si wafer volume**
  round beampipe ϕ = 28 mm
  θ=30 mRad @ z=500 mm
  Multi. scattering sigma= 50 µm

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

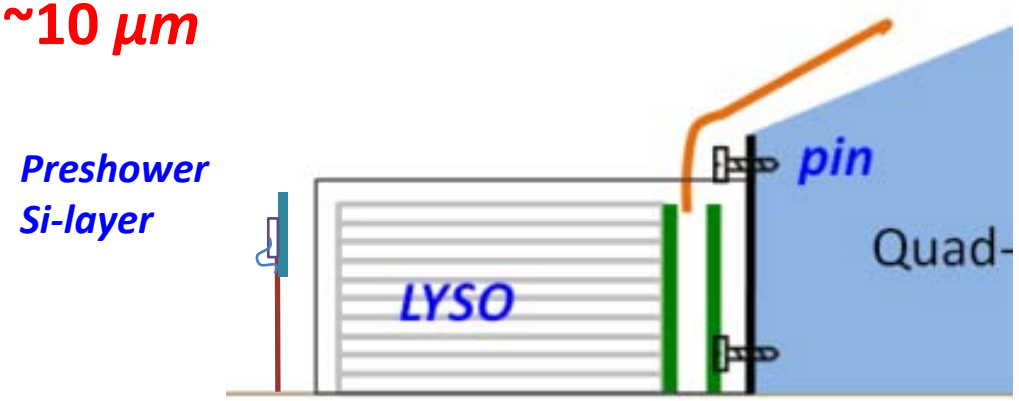
➔ *fire 100 strips @ 30 mRad*

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



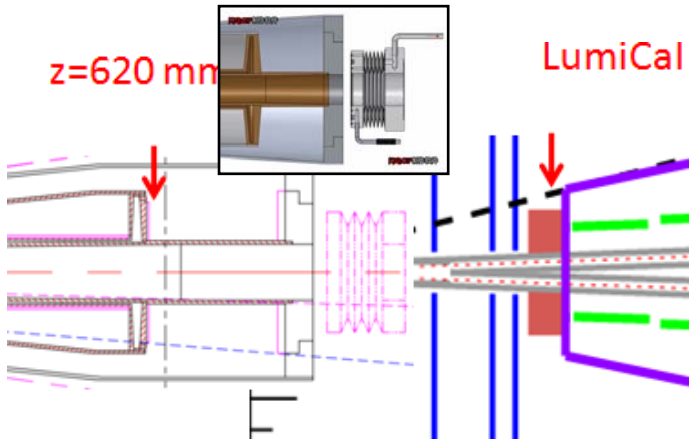
LumiCal LYSO+SiPM calorimeter

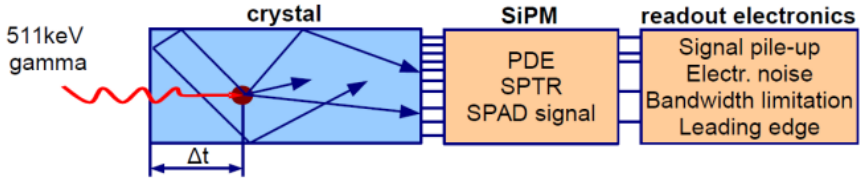
- ***Upstream materials:***
  beam-pipe, flange ➔ ***~5 X0***
  shower smearing → shower center ~1 mm precision
- ***Pre-shower Si layer for e/γ ID :***
  add Si-wafer: LYSO front is ~ shower-maximum position
- ***Readout of SiPM :***
  is compact behind LYSO bars of 2x2 mm² surface
- ***Assembly precision:***
  LYSO ring ~50 kg, supported by alignment pins/screws, ~100 µm is sufficient
  fabrication precision can reach ***~10 µm***

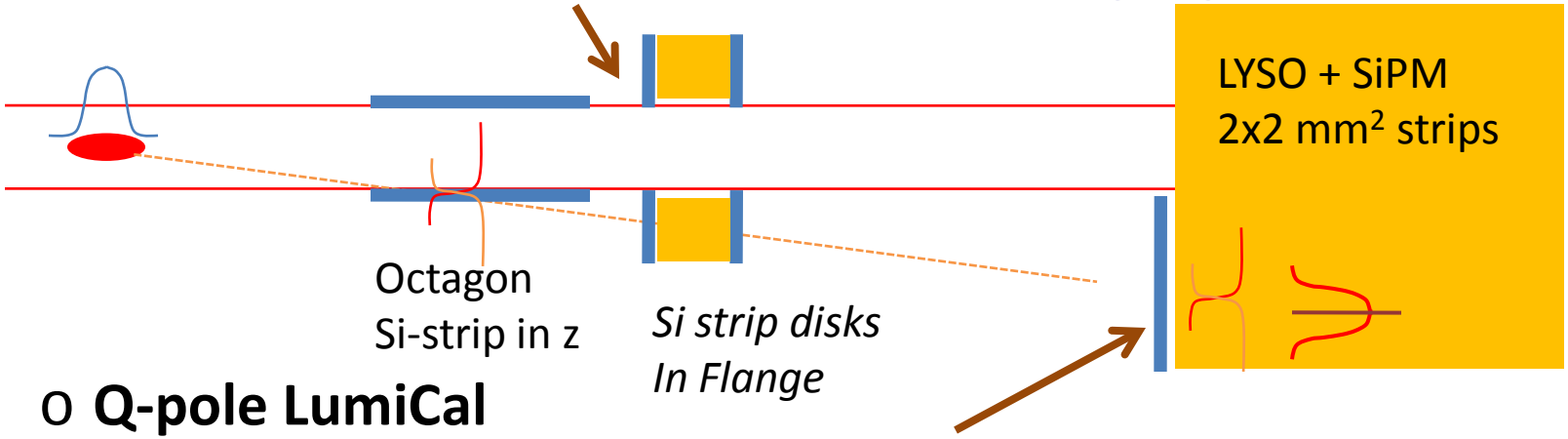


LumiCal Calo options

- **Calorimeter options**
  spatial resolution is not good
  LYSO + SiPM is compact
  minimize space for electronics
- **Flange/LYSO front**
  add Si-wafer as preshower
  for e/γ ID, NLO Bhabha etc



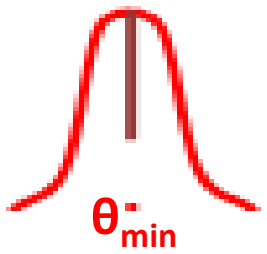




- **Q-pole LumiCal**
  100 mm long LYSO strips
  for ID beam electron with EM shower

Summary

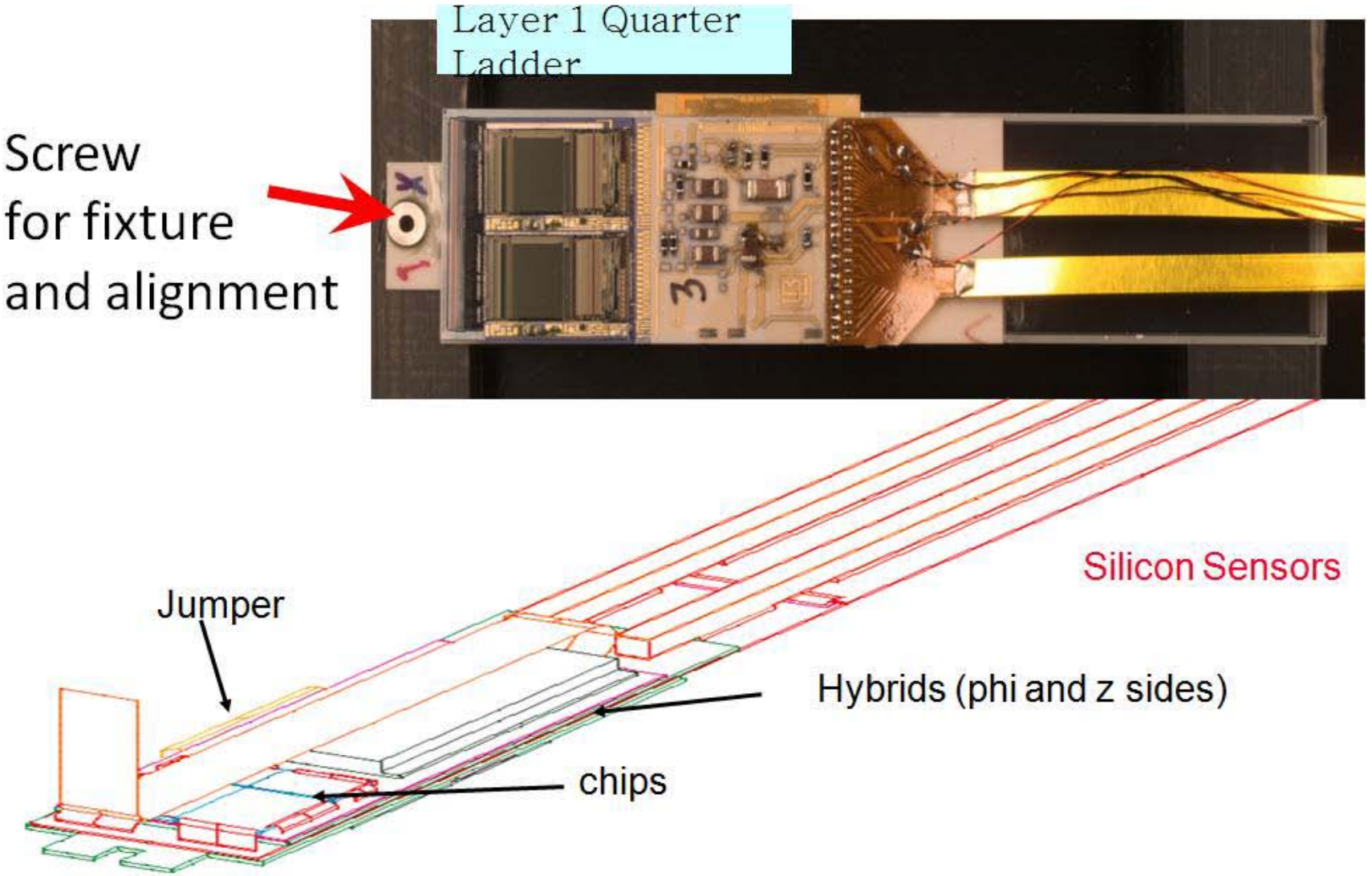
- Bhabha detection studied for luminosity precision
  $\delta L/L \sim 10^{-4}$
- With beampipe $\phi = 28$ mm, $\vartheta_{min} \sim 30$ mRad
  Bhabha X-section matches to Z(qq) pole
- electron θ resolution at ϑ_{min} edge :
  $\delta L/L \sim 10^{-4} \rightarrow \sigma_{\vartheta min} = 1.5$ μRad
- ***Si-ladders*** surrounding beam-pipe :
  θ is measured in Z, $\sigma_{\vartheta min} \rightarrow \sigma_Z = 25$ μm
- Multiple-Scattering of beampipe RMS in Z = 50 μm
  → Si-ladders measure the MS profile
  $\sigma_{\theta min}$ estimated for the measured MS profi
  → Si-ladder of 100 μm pitch in Z
  $\sigma_Z^{measured}$ is expected for ~ 10 μm



Backup
CDF tracker assembly

CDF L00 assembly

SVXII Assembly



Silicon Detector Installation