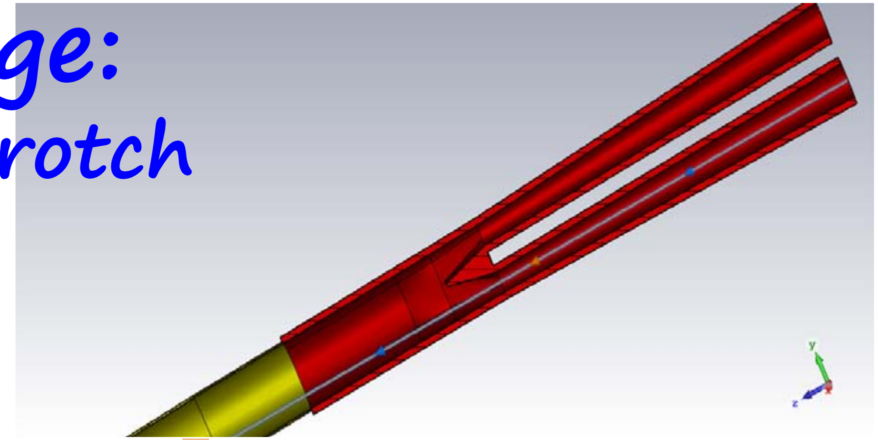
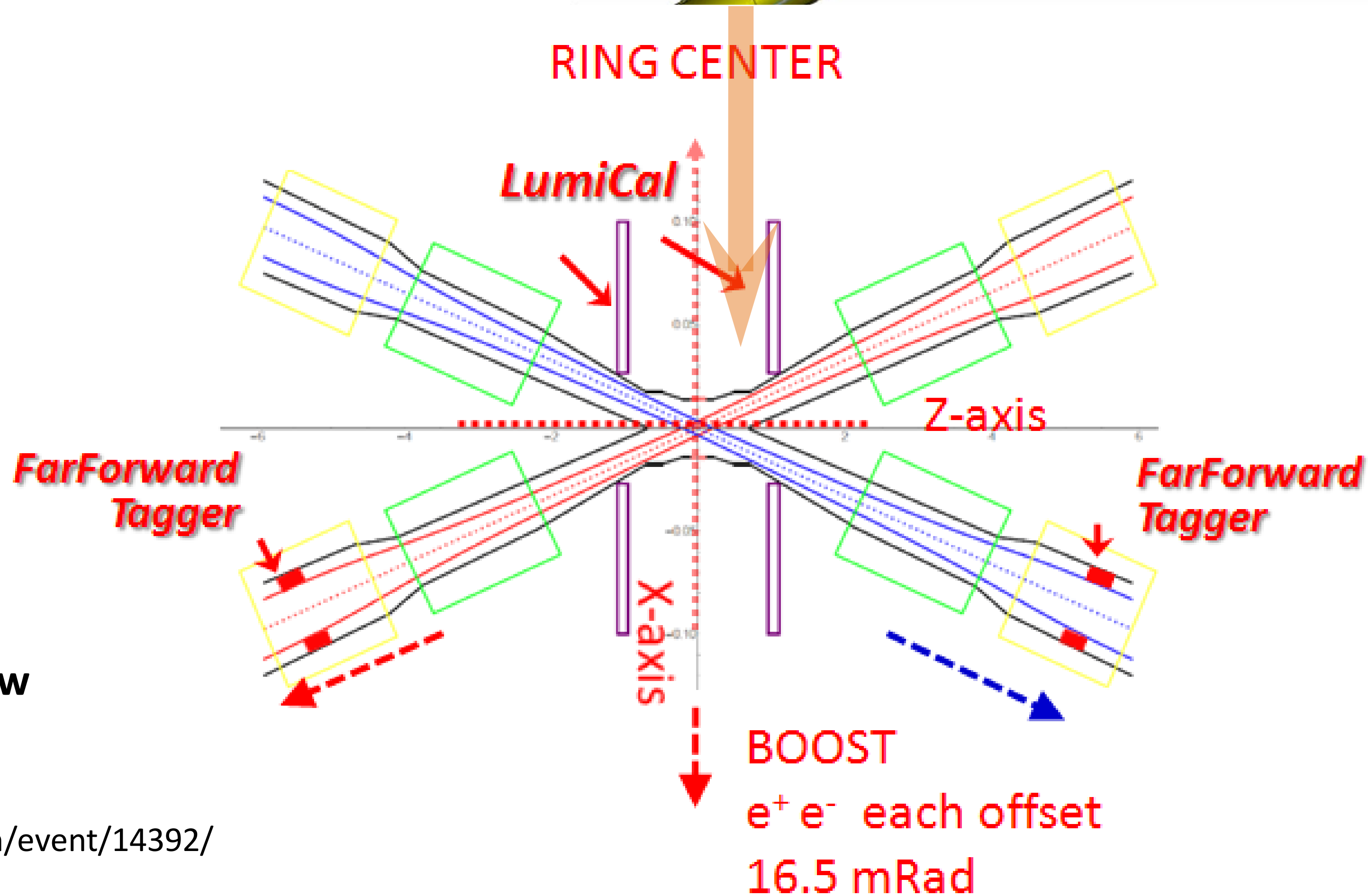
LumiCal behind Flange:
28-40 mm pipe with Y-crotch and dual 20mm pipes



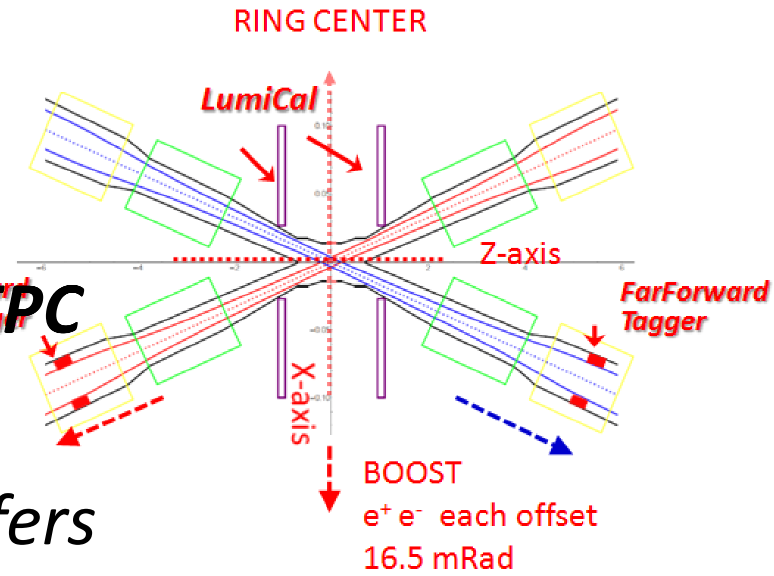


Suen Hou 侯書雲
suen@sinica.edu.tw

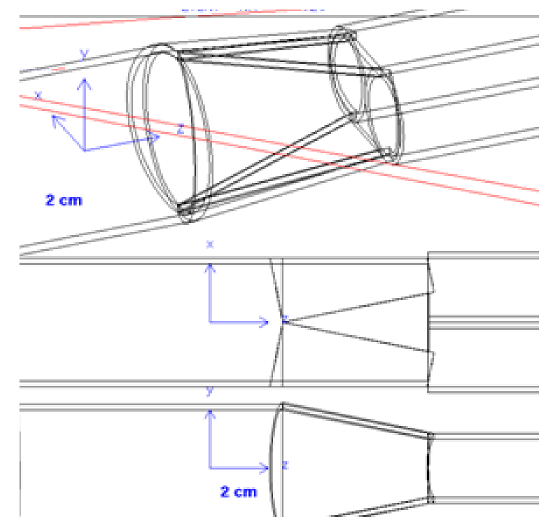
2021.10.22

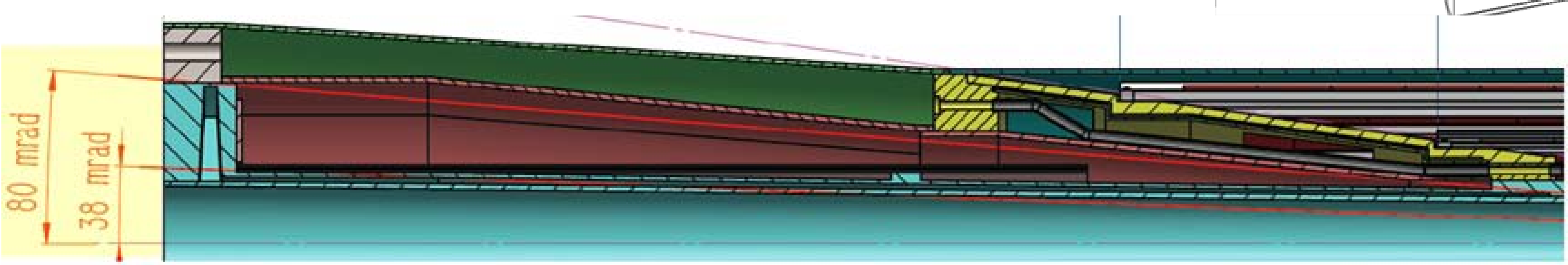
https://indico.ihep.ac.cn/event/14392/

outline



- ***Bhabha Luminosity basics to CEPC***
- ***Multiple Scattering***
  before Flange: inner Lumi Si-wafers
  after Flange: Y-crotch, Q-pole front
- ***Cross sections with 28-40 round pipe***
  Y-crotch acceptance
- ***Dual 20mm pipes gain cross section***





Luminosity by Bhabha

- ***For Stanard Model Cross sections***

  Z-lineshape dominant : $e^+e^- \to Z \to q\bar{q}$

  SM events: $\boxed{N = \sigma \cdot \int L}$

- ***Luminosity*** L

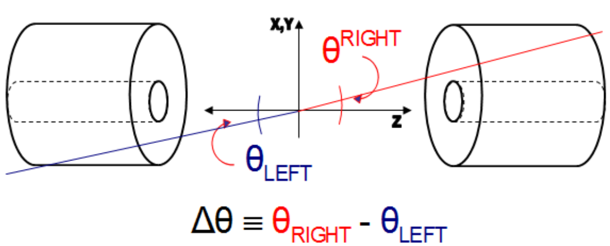
  by counting Bhabha elastics scattering

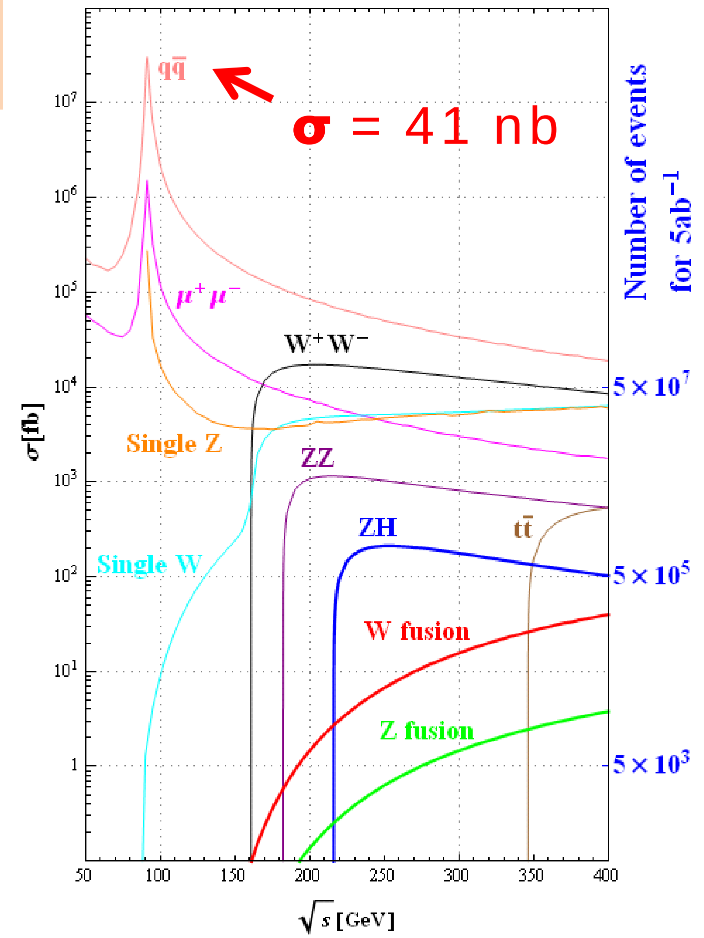
  $$\boxed{e^+e^- \longrightarrow e^+e^-}$$

  – QED process, ***theoretical < 0.1% precision***
  – detect a pair of ***back-to-back*** e^+e^-

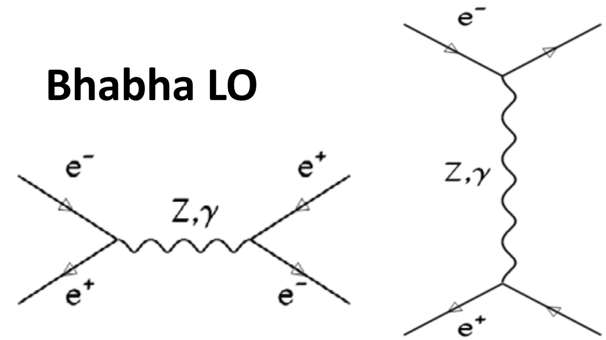
Bhabha cross section

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





Bhabha LO



Luminosity pricision

offset on the **mean of** θ_{min}

➔ ***LUMINOSITY error***

Systematic error, Center-of-Mass frame

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

$\delta L/L < 10^{-3}$ *for Higgs factory*

→ ***$\delta\vartheta$ = 15 µRad*** **@θ_{min}= 30 mRad**

→ ***OFFSET on the***

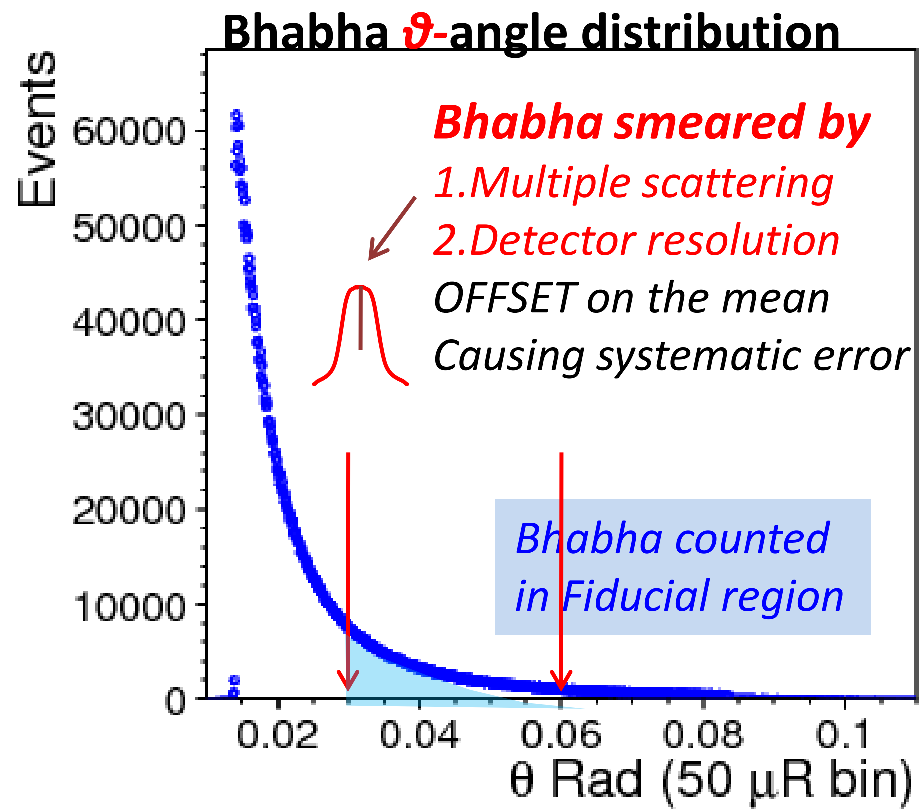
"mean of fiducial edge"

cause for δN on Bhabha counting

@z = 1000 mm, *$\delta\vartheta$ = 15 µRad*

corresponds to

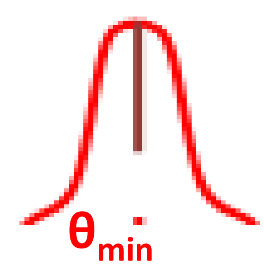
dz = ***0.1 mm*** or *dr = Rxϑ* ***= 3 µm***



LumiCal design goal:

- *Spatial resolution as sharp as possible*
- *Describe the* ***reso./MS shape of $\delta\langle\theta_{min}\rangle$***

  bin resolution ~ 3 µm in r, or 100 µm in z

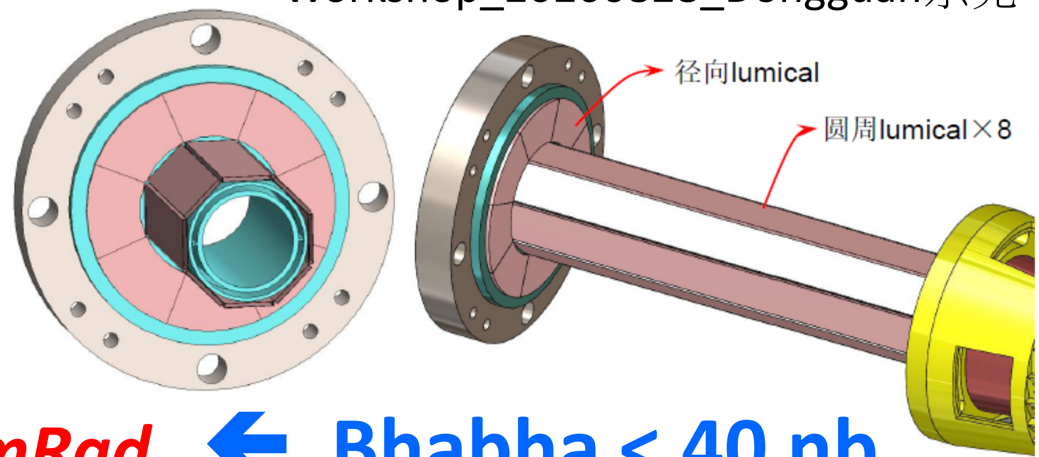


Beam-pipe, 28-40mm Round

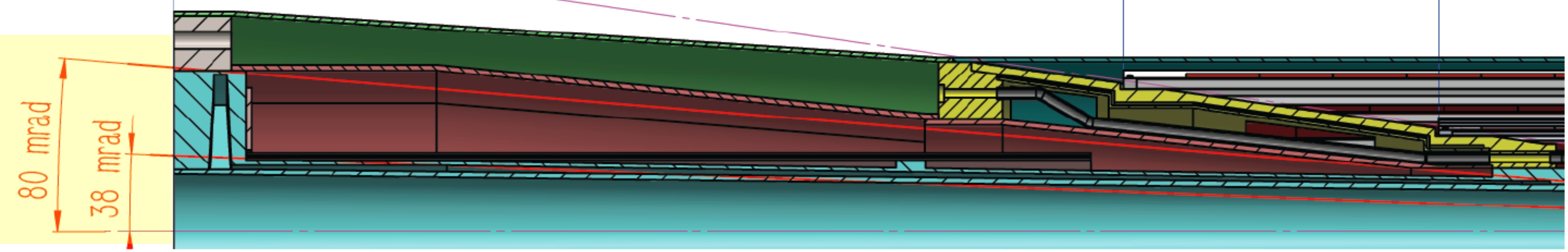
Workshop_20200828_Dongguan东莞

5.5 Preliminary design of lumical

- Detection Angle range: 38~80mrad
- On the detection path, as little mass as possible
- The structure of lumical is not yet determined, so the support and cooling structure should be further optimized and improved.



LumiCal access, ϑ_{min} = 38 mRad ← **Bhabha < 40 nb**



Al pipe x = 200 - 700 mm, inner 0.5mm, outer 0.35 mm thick

Inner diameter @Z=200 φ = 28 mm

Inner diameter @Z=675 ***φ = 40 mm*** *→ atan =* ***29.6 mRad***

Flange z=675~700, dia.=40 mm flat

Corner of ***38 mRad*** *@ Z=(700-25) mm*

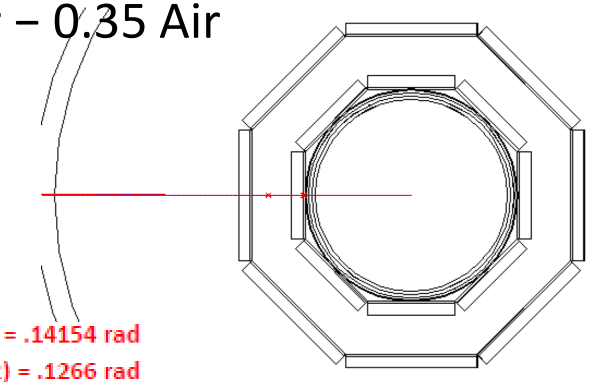
*Radius = (700-25)*tan(.038)* ***r= 25.66 mm***

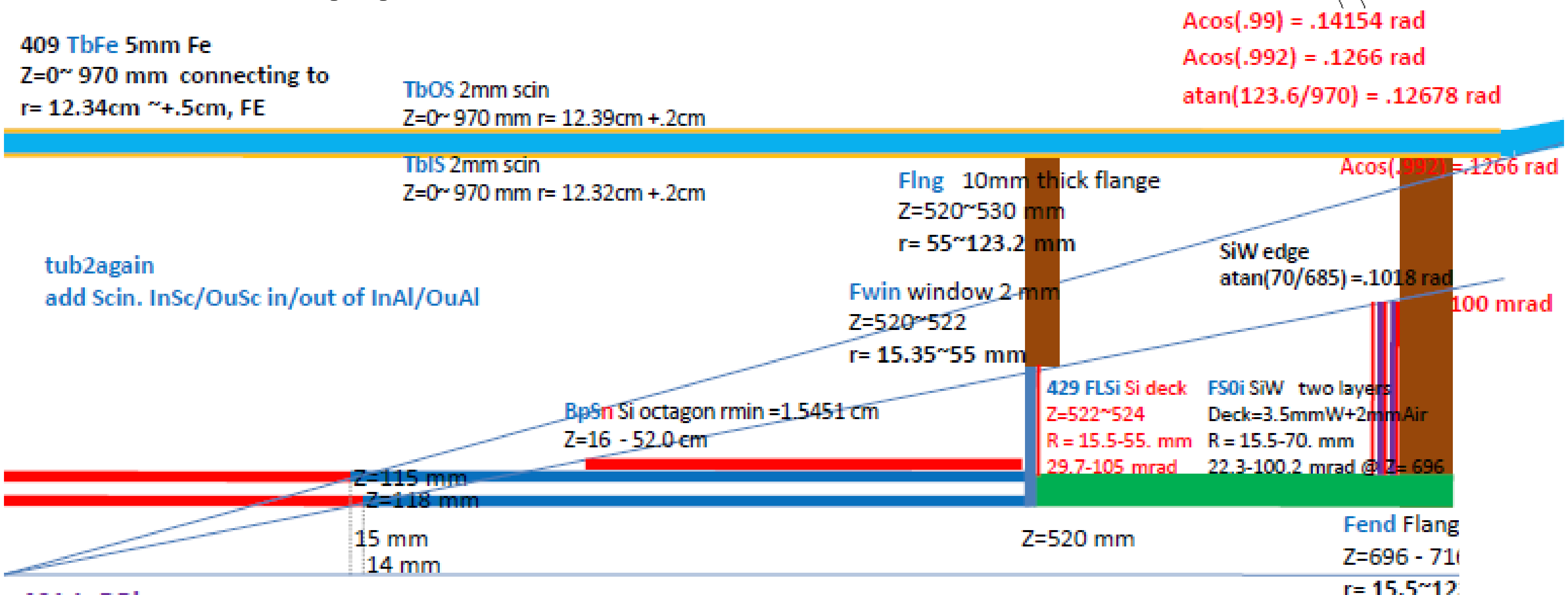
1) Simple 28mm straight pipe

- Tube design, ϕ=28 mm, thickness (mm): 0.5 Al – 0.5 Air – 0.35 Air
- Si wafer attacked tightly
- Scintillator layer surrounding Al pipe

➔ observe Multiple-Scattering within Al pipe,

Δz in Al-pipe: 20 – 40 mm





401 InBPipe

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

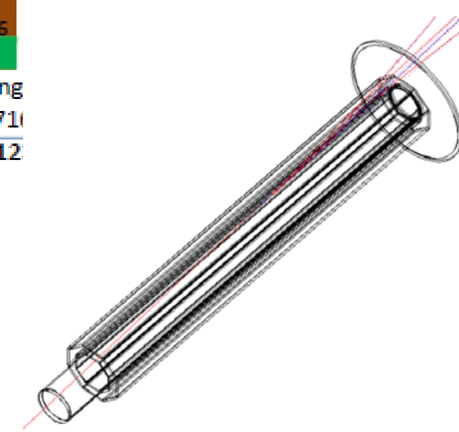
InAl Inner Cu pipe
Z=118~500 mm,
inner diameter 28 mm 0.5mm thick

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

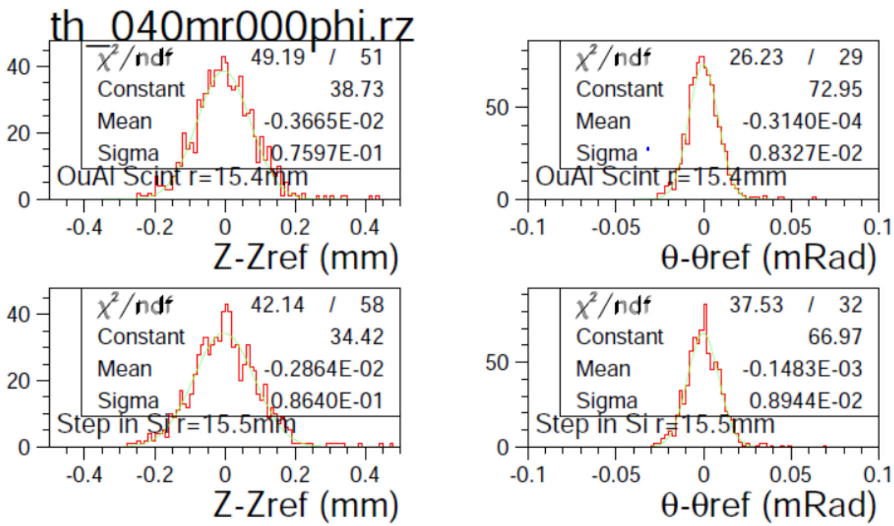
OuAl outer Al pipe
Z=0~115 mm
inner r=28/2+1 mm, 0.35 mm thick

2020 LumiCal geom



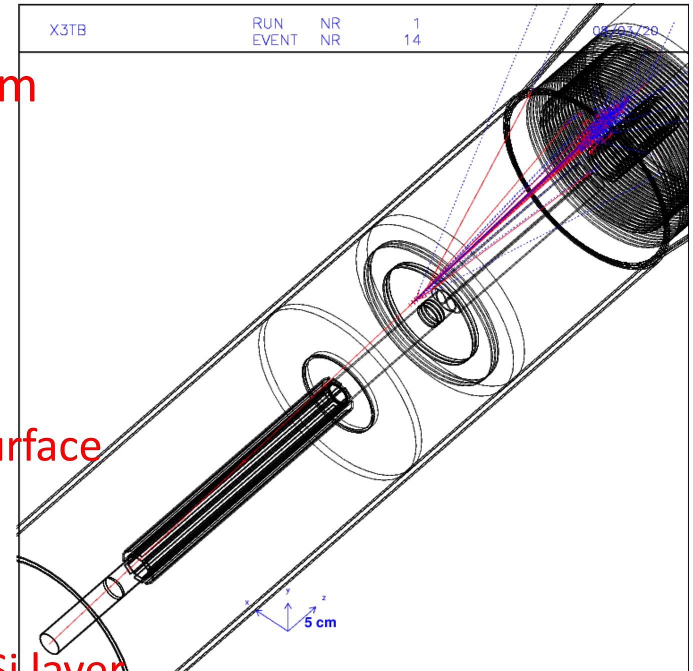
1) 28mm pipe Multiple scattering

- ***50 GeV electron*** traversing Al-pipe (mm): 0.5 Al – 0.5 Air – 0.35 Air @ fixed theta, phi=0°
- ***Multiple scattering deviation*** simulated for ϕ=28 mm
  1. exiting Al-pipe (a Scintillator layer on surface)
  2. no air-gap, Si-layer attached



dz, dθ
on Al-pipe surface

dz, dθ
on Octagon Si layer



50 GeV (θ,ϕ)	σ (Z)	σ(θ)	1/tan(θ)
e (40 mR, 0°)	86 μm	8.9 μRad	25.0
e (55 mR, 0°)	37 μm	7.3 μRad	18.2
e (60 mR, 0°)	28 μm	6.5 μRad	16.6
e (70 mR, 0°)	19 μm	5.8 μRad	14.3

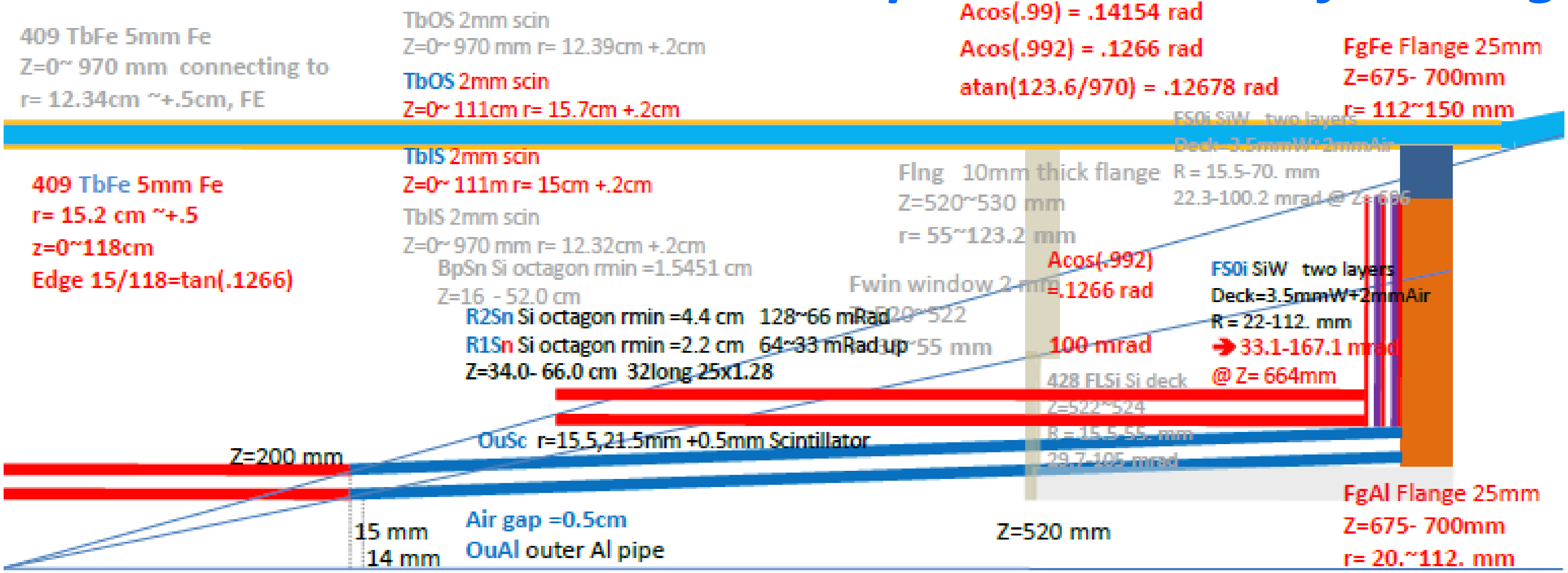
θ to z: r/z = tan θ

2) 28-40mm cone pipe (2021)

- Tilt the Al pipe from ϕ=28 mm to ϕ=40 mm
  thickness (mm): 0.5 Al – 0.5 Air – 0.35 Air
- Si wafer parallel to z-axis r_{min}=22mm

➔air gap to Al-pipe, large Multiple Scattering

poor lumi si-wafer design !



401 InBPipe full +-200 mm p9

InBP Inner Be pipe
Z=0~200 mm,
inner diameter 28 mm 0.5mm thick

OuBP outer Be pipe
Z=0~200 mm
inner radius 28/2+1 mm 0.35mm thick

Z=200~675 mm
@200 r=28/2+1 mm, 0.5mm thick
@675 r=40/2+1 mm, 0.5mm thick

InAl Inner Cu pipe
@200 inner r=28/2 mm 0.5mm thick
@675 inner r=40/2 mm

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

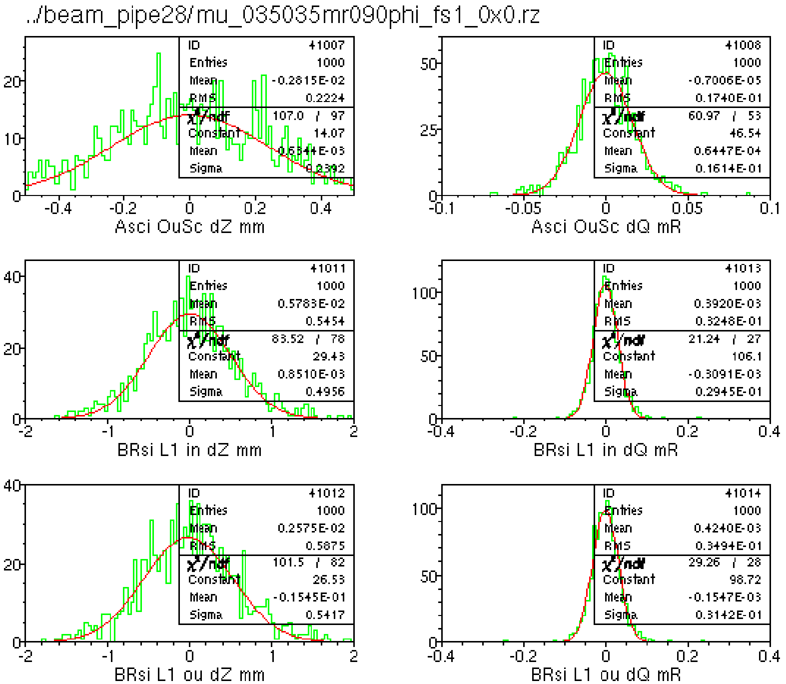
Fend Flange 20mm
Z=696 - 716
r= 15.5~123.2 mm

2) Multiple Scattering on Si ring (parallel)

- Al-pipe tilt 12.6 mRad (ϕ28 to 40 mm)
- Si-layer (r=22mm) parallel to z-axis

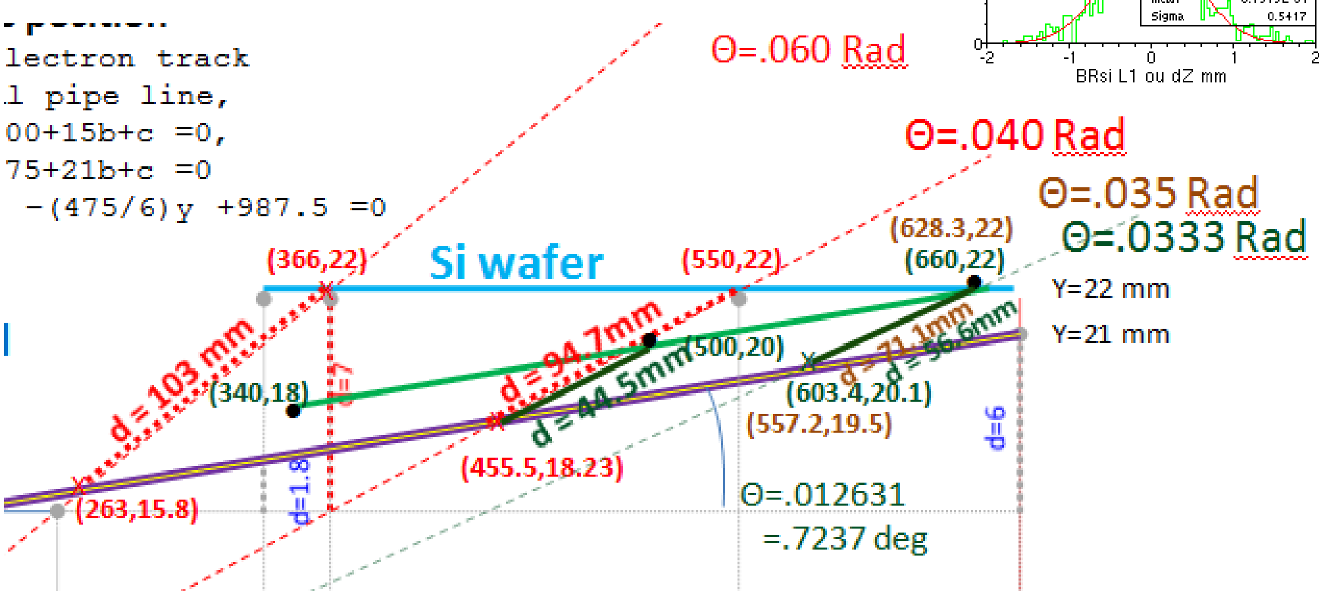
➔ air-gap from IP ~ 100 mm

➔ multiple scattering effect is magnified !!



Compare MS on Octagon Si layer, ***primary track***

mu (θ,ϕ)	σ(Z) Si[1st]	σ(θ) Si[1st]	1/tan(θ)
(35 mR, 90°)	542 µm	31 µRad	28.6
(40 mR, 90°)	489 µm	37 µRad	25.0
(55 mR, 90°)	291 µm	41 µRad	18.2



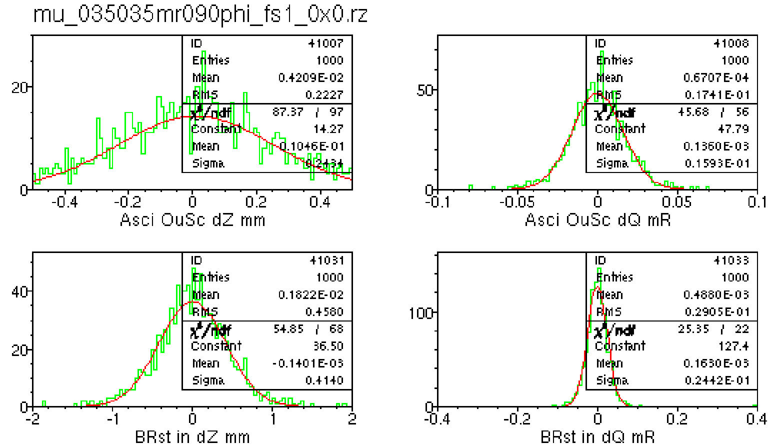
2) Multiple Scattering on Si ring (stick-on)

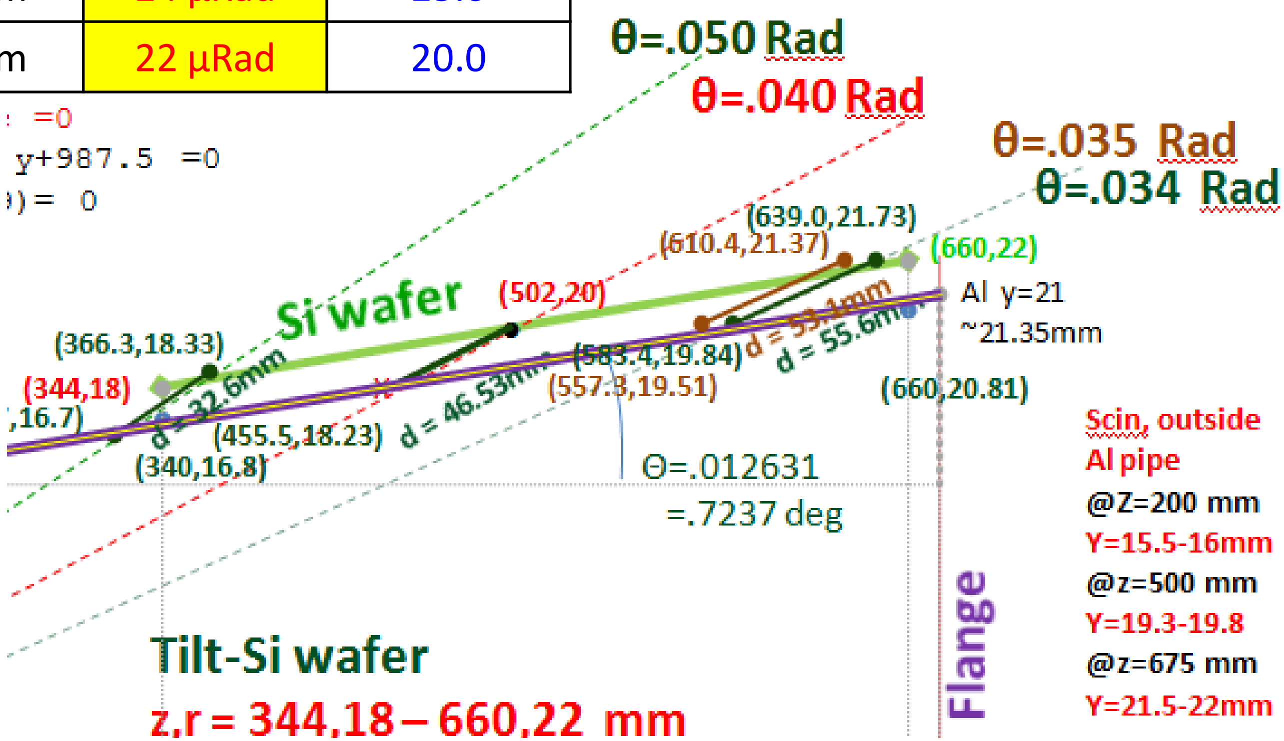
- Al-pipe tilt 12.6 mRad (ϕ28 to 40 mm)
- Si-layer parallel to Al-pipe, gap = 1mm

➔ air-gap from IP ***~ 50 mm***

Compare MS on Octagon Si layer, ***primary track***

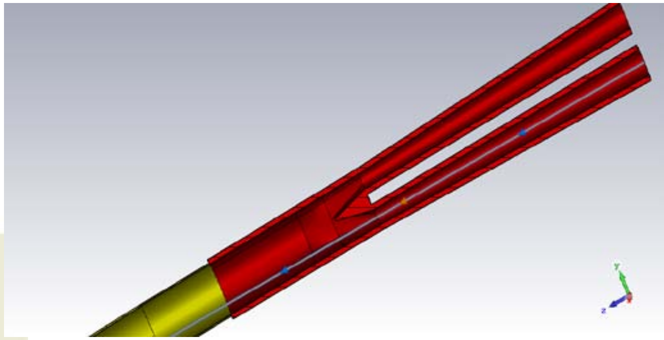
mu (θ,ϕ)	σ(Z) Si^{1st}	σ(θ) Si^{1st}	1/tan(θ)
(35 mR, 90°)	475 µm	28 µRad	28.6
(40 mR, 90°)	301 µm	24 µRad	25.0
(50 mR, 90°)	161 µm	22 µRad	20.0

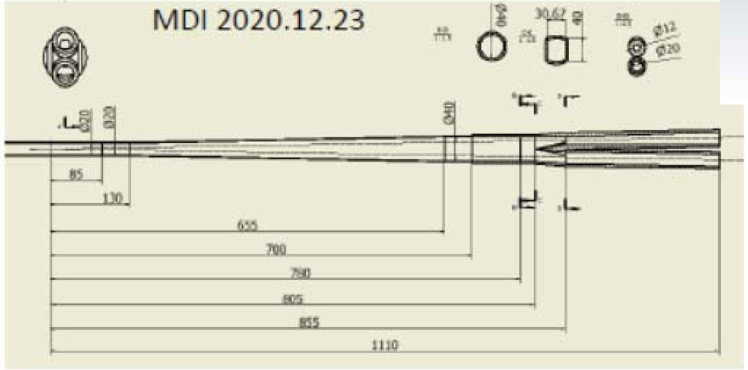


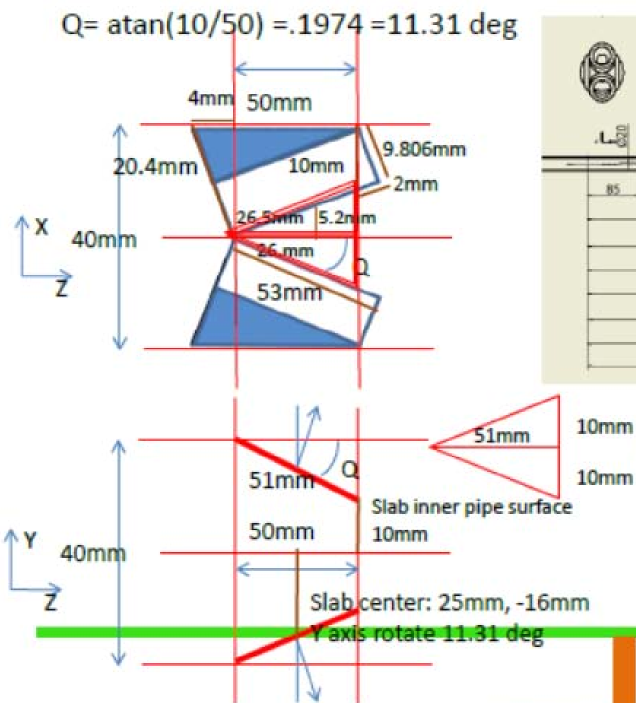


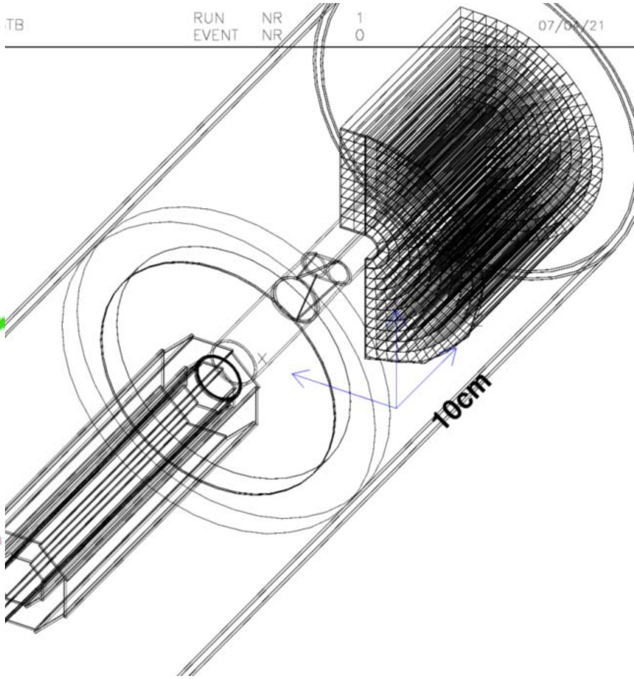
Multiple Scattering behind the Flange

the ***y-crotch*** ϕ=40 to dual 20 mm pipes
is ***a low-mass, high cross section*** window
for Bhabha



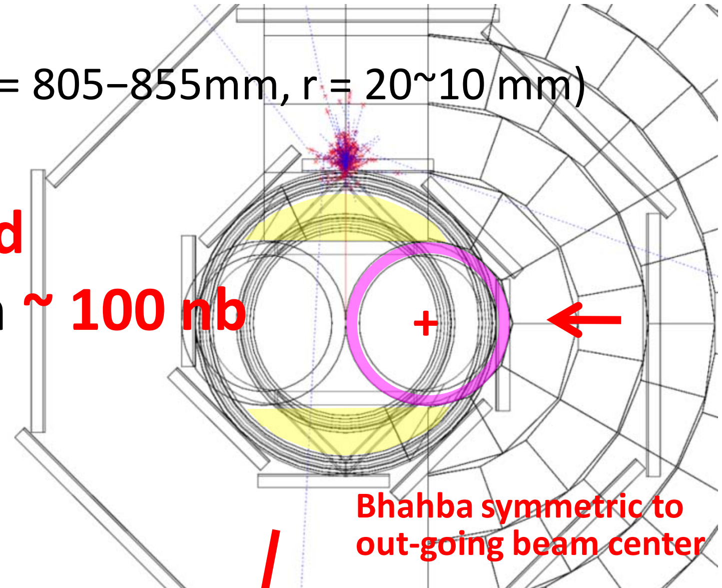




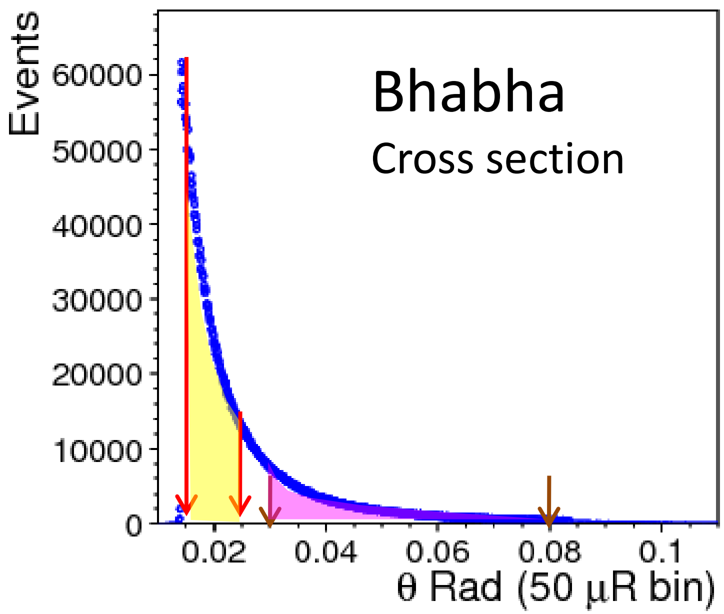


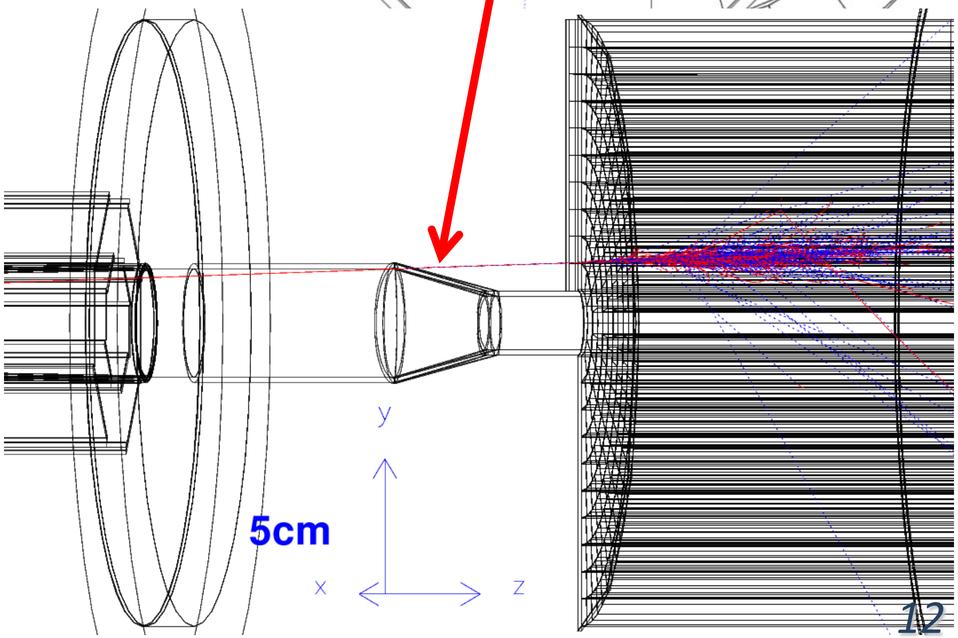
3) Y-crotch window

- Duckbill slope on y-axis is **200 mRad**, (z = 805–855mm, r = 20~10 mm)
  electron traversing distance **~ 10 mm**
- Window on lab y-axis: **θ = 15 – 25 mRad**
  Bhabha cross section in clean phi region **~ 100 nb**
- Electron θ measured by Si r-ϕ disk
  before LYSO

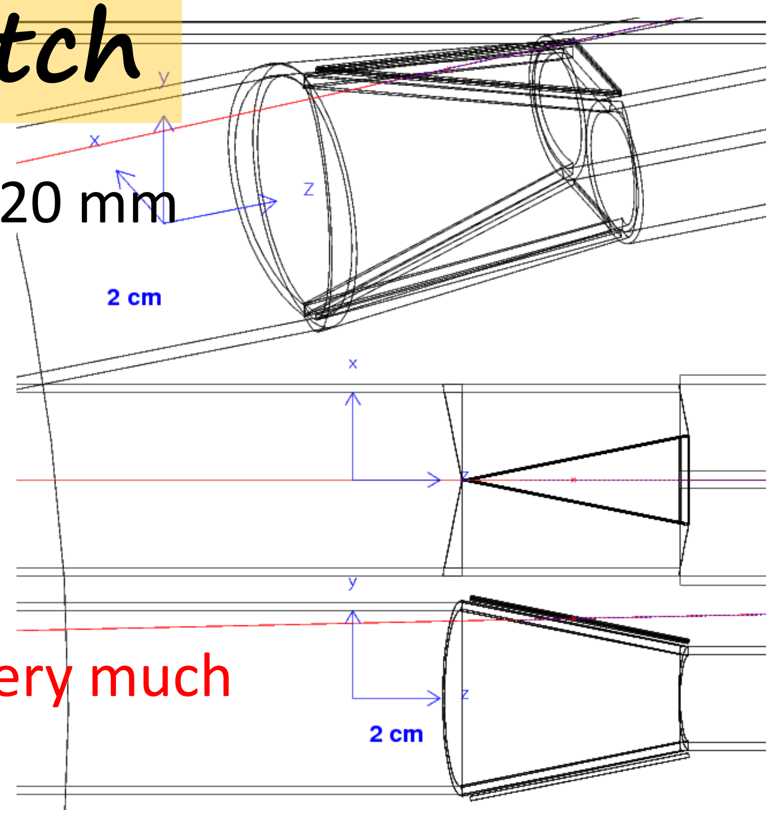


Bhahba symmetric to
out-going beam center

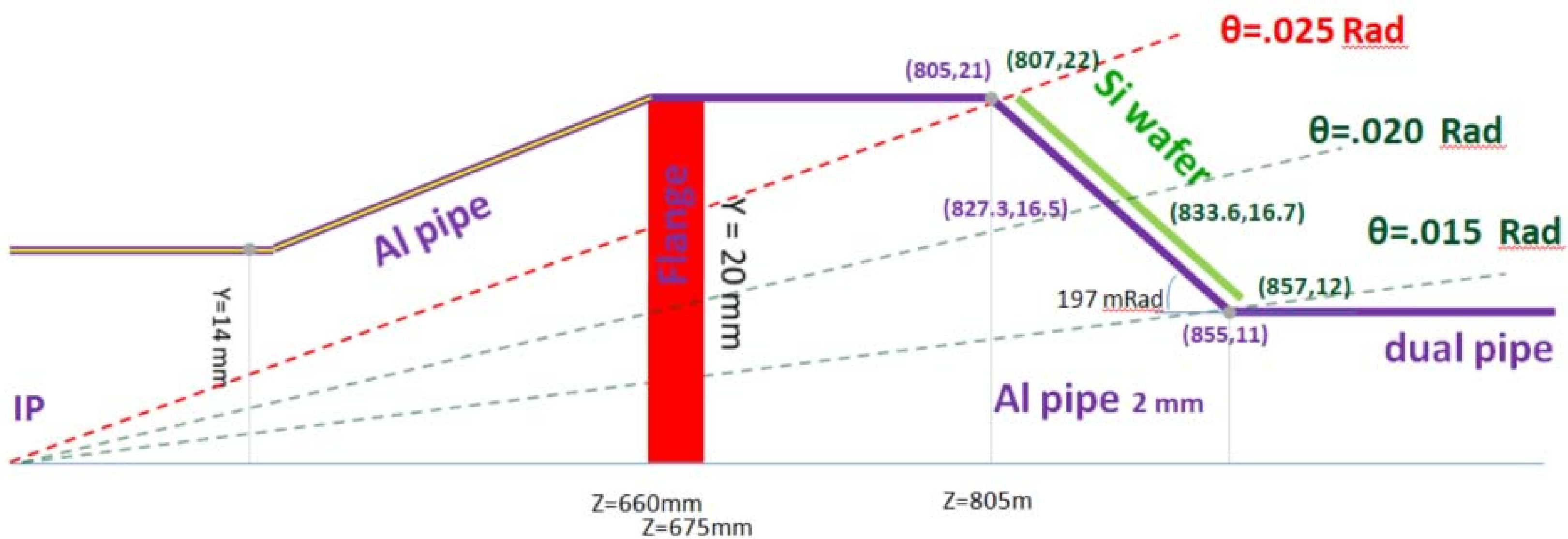




3) Si-wafers on Y-crotch



- Round pipe ϕ=40 mm to dual pipes ϕ=20 mm
  Slabs on top/down of the Y-crotch
  z= 805 to 855 mm
  slope = 197 mRad (11.3 deg)
- Si wafer 1mm above
  ➔ air gap from IP: ***6~6.5 mm***
  Multiple Scattering effect suppressed very much



3) LumiCal Si-wafer spatial resolution

50 GeV electron, *all hits* on Si wafers

(primary e⁻ and secondaries)

Scan vertically phi = 90°

through Y-crotch window

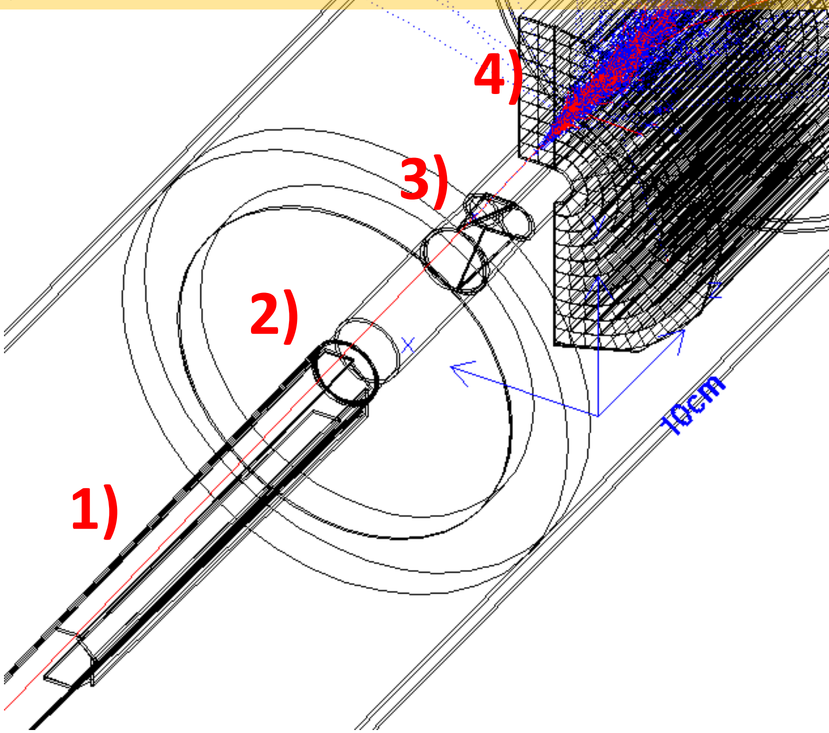
Multiple scattering estimated on

1) Octagon surrounding Al-pipe

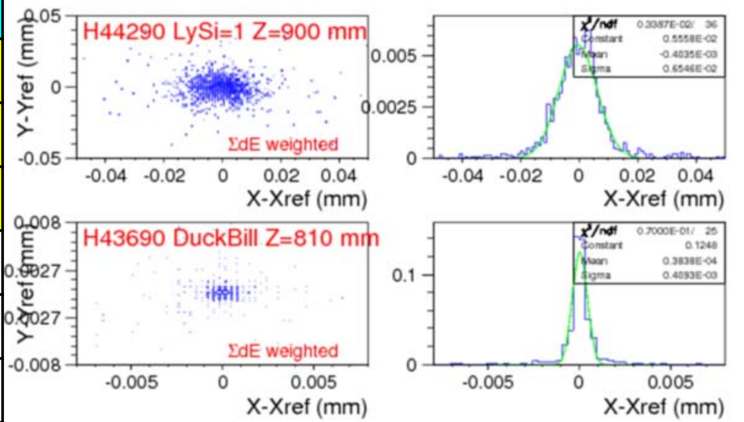
2) Flange Si-disk

3) Y-crotch up/down slabs

4) LYSO front Si-disk



Lab (θ,φ)	1) σ(z) Oct Si	2) σ(x) Flg Si	3) σ(x) Y-cr. Si	4) σ (x) Ly-Si
e (15 mR, 90°)	–	–	0.55 μm	5.3 μm
e (20 mR, 90°)	–	–	0.41 μm	6.5 μm
e (25 mR, 90°)	–	–	0.88 μm	9.8 μm
e (30 mR, 90°)	–	–		95 μm
e (40 mR, 90°)	620 μm	52 μm		129 μm
e (55 mR, 90°)	373 μm	58 μm		114 μm
e (60 mR, 90°)	308 μm	65 μm		111 μm



4) dual-20mm pipes, Lumical option

- **round pipe ϕ<20 mm @IP**
  split slowly to dual pipes, ϕ=20 mm, at Y-crotch

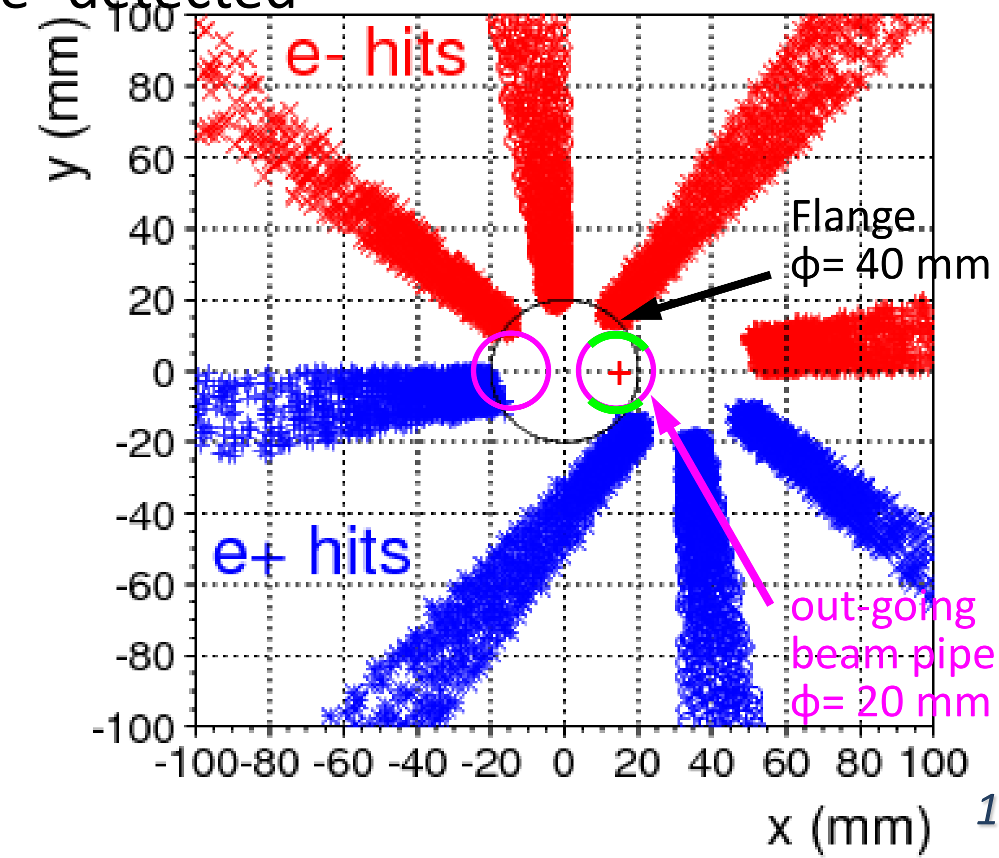
1) LumiCal Si wafers,   vertical y-axis   **r_{min} = 10 mm**
   ➔ **gain very much Bhabha X.section**

2) Si wafers parallel to beam center
   ➔ **multiple scattering** acceptable   **σ(θ) ~10 μRad**

Boosted Bhabha distribution

- Bhabha symmetric to out-going beam center boosted by the 33 mRad beam crossing
  (x,y) = (16.5, 0) @ z = 1000 mm
- High cross-section, low mass region:
  phi ~ 60º to 120º *to beam center*
- Bhabha acceptance: both $e^+ e^-$ detected
  Lab frame @ z = 1000 mm
  dual beampipe: r = 10 mm
  y-axis: |y|>10 mm,
  x-axis: (± 43 mRad to out-going beam center)
  Lab θ(e^+) > 26.5 mRad
  Lab θ(e^-) > 59.5 mRad

Lab frame ***@z=1000***
Bhabha distribution



Bhabha cross-section, BHLUMI calculation

Beam crossing 33 mRad,

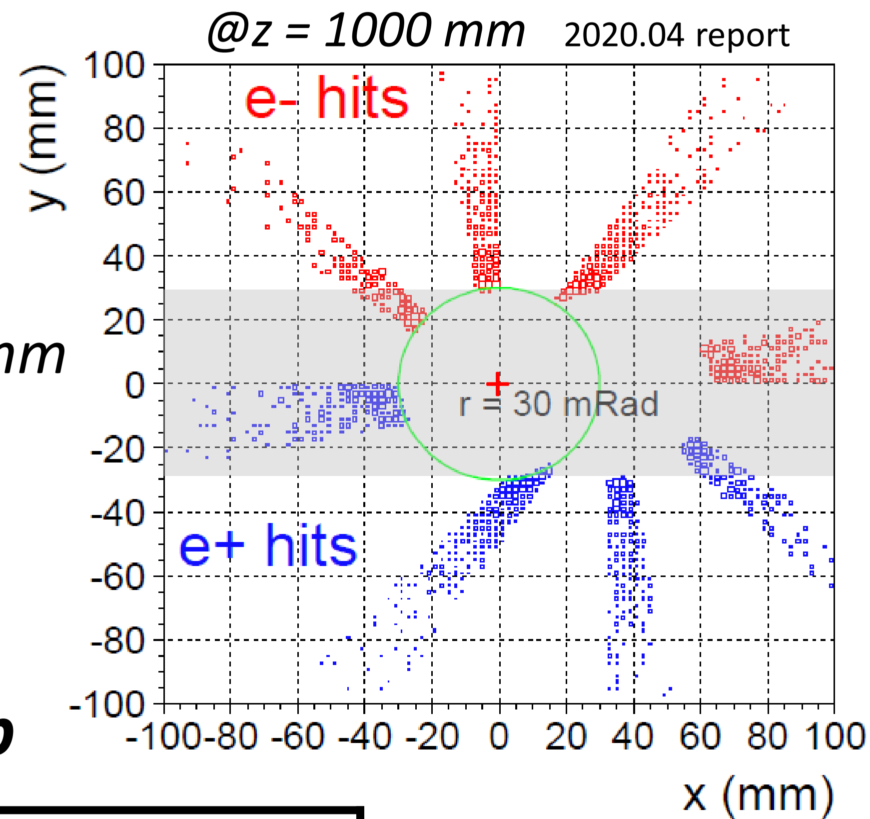
- $e^+ e^-$ boosted to +x, off ring center
- back-to-back symmetric to out-going beam center (x,y) = (16.5, 0 mm) *at z = ±1000 mm*

50 GeV beam, both $e^+ e^-$ detected

In fiducial range of *r > 30 mRad*

***ϑ range* = 30 – 80 mRad**

Bhabha cross section *> 50 nb*



BHLUMI, 50 GeV Bhabha boosted for 33 mRad crossing			
CMS 10 ~ 80 mRad		LAB detect ***both*** **electrons**	
BARE1		**off beampipe full phi coverage**	**off beampipe cut off ±30 mm**
Nevents	457232	29194	19216
Xsec (nb)	1168.3	**74.60 nb**	**49.10 nb**

Summary

- **To gain Bhabha X.section > 50 nB**
  pushing for θ_{min} < 30 mRad, favoring vert. direction
- **Precision luminosity, $\Delta\int L \sim 10^{-4}$**
  minimal multiple scattering effect
- **LumiCal Si wafer**
  before Flange, surrounding beampipe
  behind Flange, on Y-crotch, extend toward Q-pole
- **Round 28-40 mm beampipe**
  Y-crotch window within 40mm is favored
  for X.sec and multi. scattering