LumiCal mechanical precision of 1μm for CEPC luminosity 10^{-4} precision

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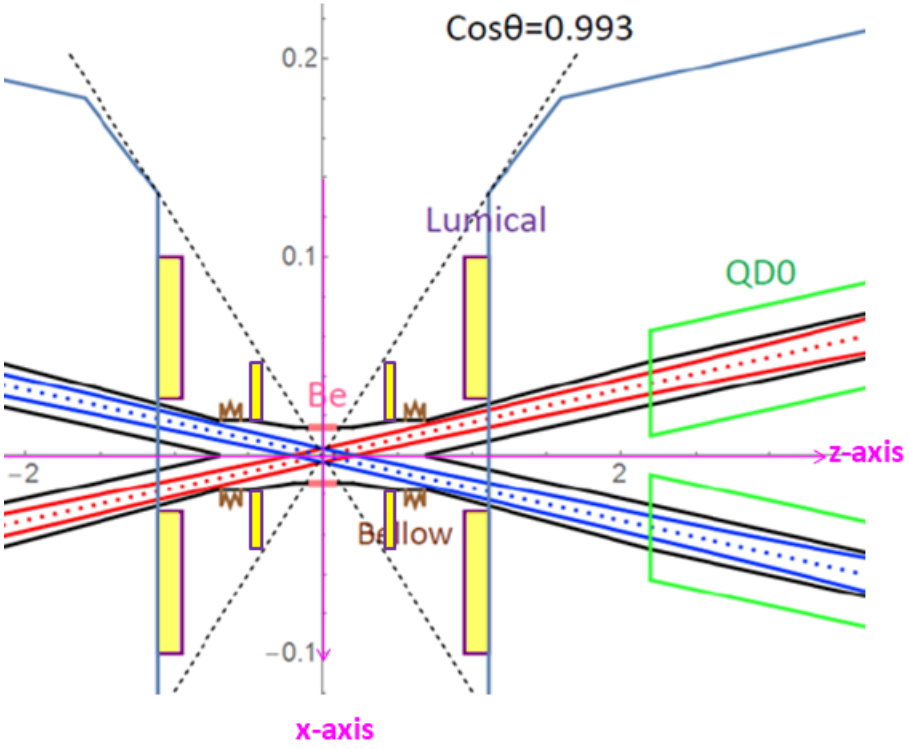
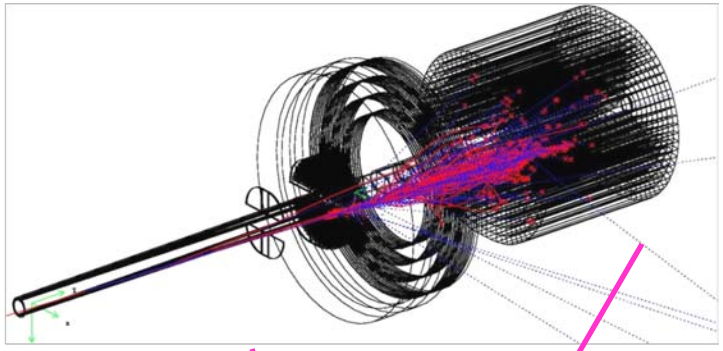
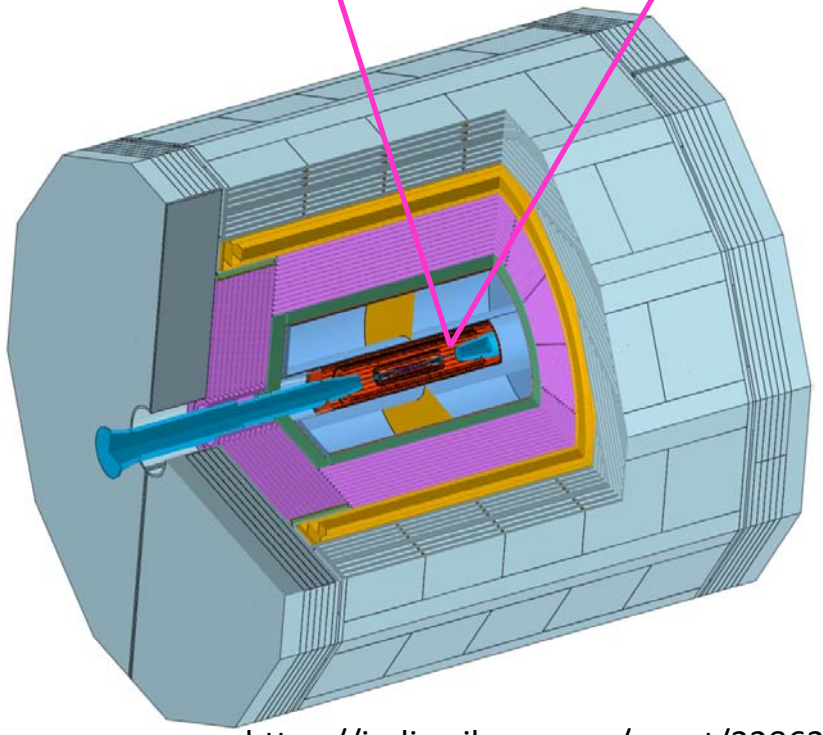
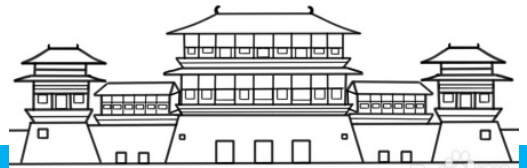






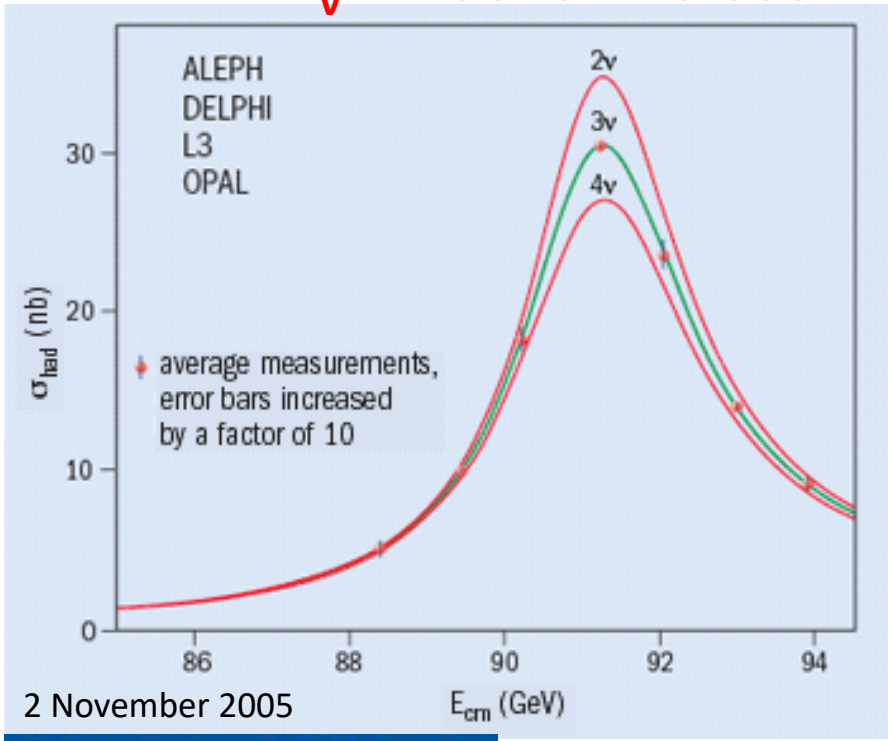


Why 10^{-4}

- **Z events: N_Z = 100** times to LEP
- Standard Model precision improve by 10^{-1}

➔ ***e^+e^-* luminosity: 10^{-4} required**

$N_\nu = 2.9840 \pm 0.0082$



LEP achievement

$M_Z = 91187.5 \pm 2.1$ MeV	2.3×10^{-5}
$G_Z = 2495.2 \pm 2.3$ MeV	1‰
$N_\nu = 2.9840 \pm 0.0082$	
Precision luminosity	**3‰**

Luminosity by counting Bhabha

e^+e^- bunch crossing, colliding luminosity

can produce …..

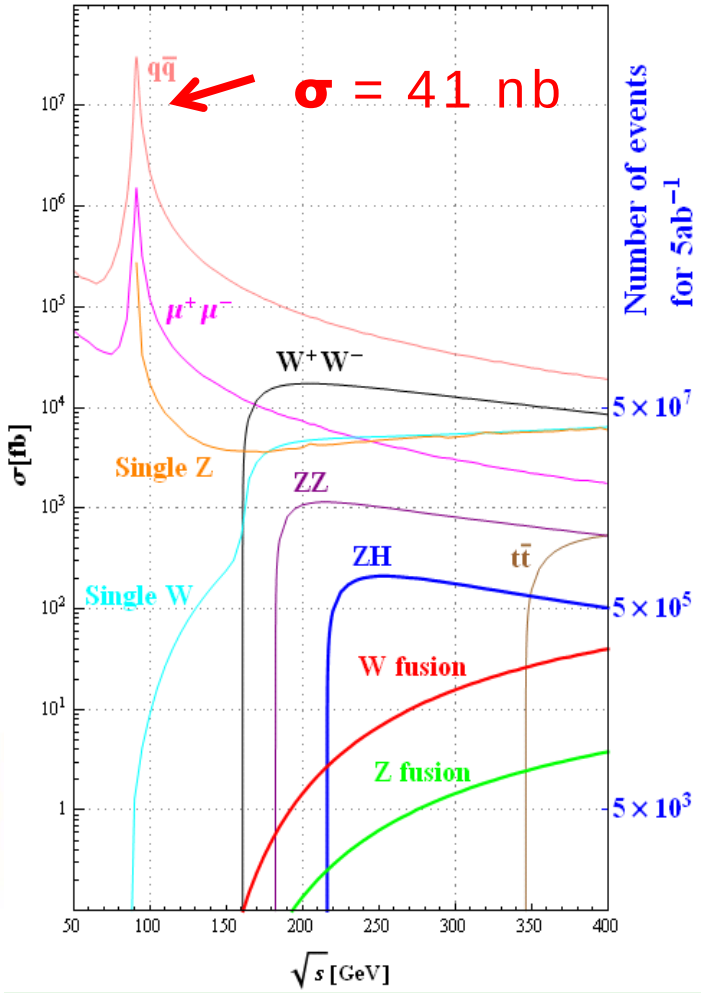
- elastic Bhabha scattering $e^+e^- \longrightarrow e^+e^-$
- ElecroWeak $e^+e^- \longrightarrow Z$

  etc..

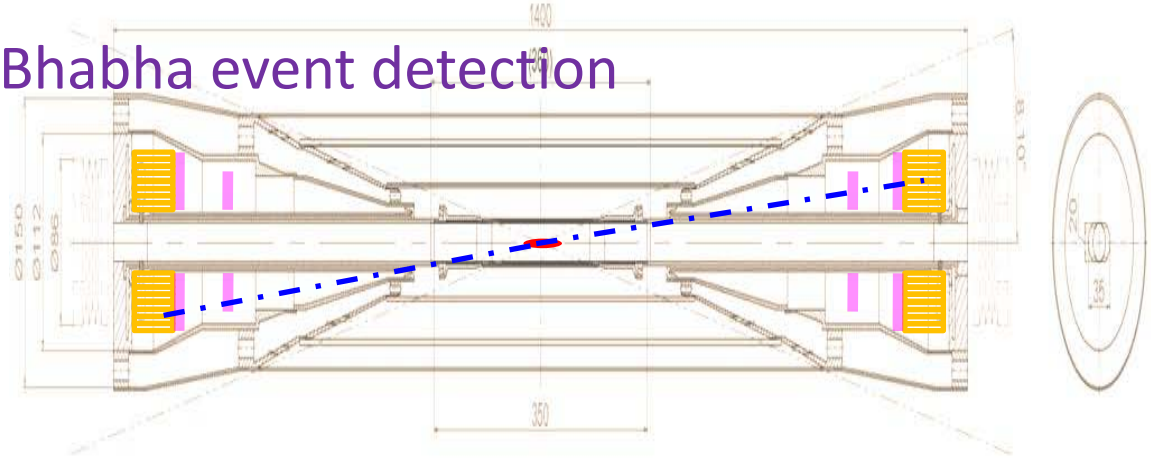
Bhabha is QED calculated to **3×10^{-4}** precision

***Count Bhabha*→ obtain online Luminosity**

→ derive SM cross sections

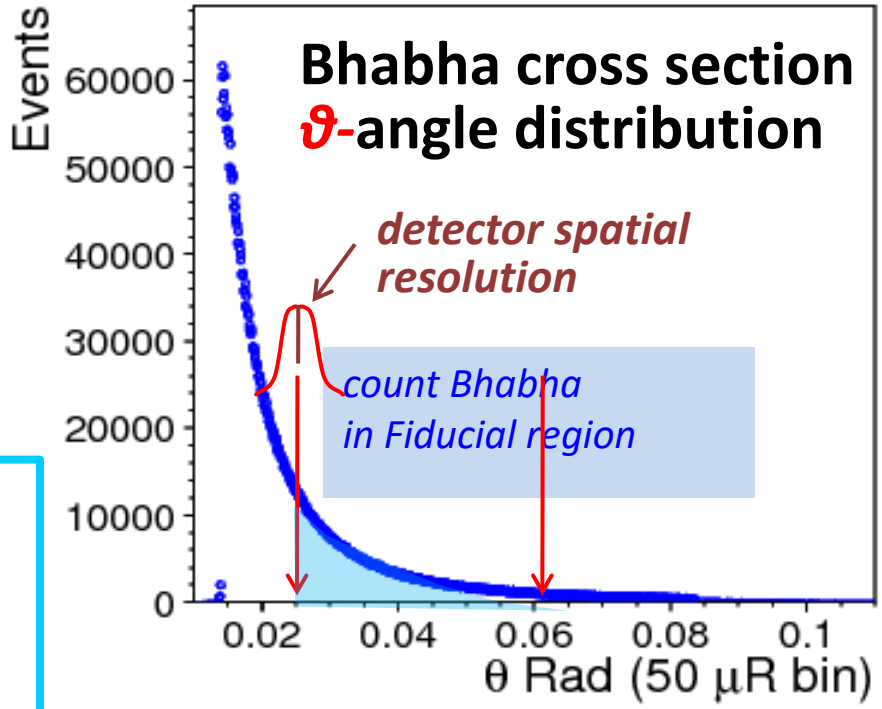


Bhabha event detection



Bhabha counting precision

- *Event counting* $N = \sigma \cdot \int L$
- *Counting Bhabha events*
  - *a pair of back-back electrons,*
  - *precision ϑ on e,e(γ) in fiducial region*



Bhabha systematic error

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

requiring $\delta L/L = 10^{-4}$

at **z = ±1 m,** θ_{min} **= 20 mRad**

→ $\delta\vartheta$ = ***1 μRad*** or ***dr = 1 μm***

error due to offset on Z

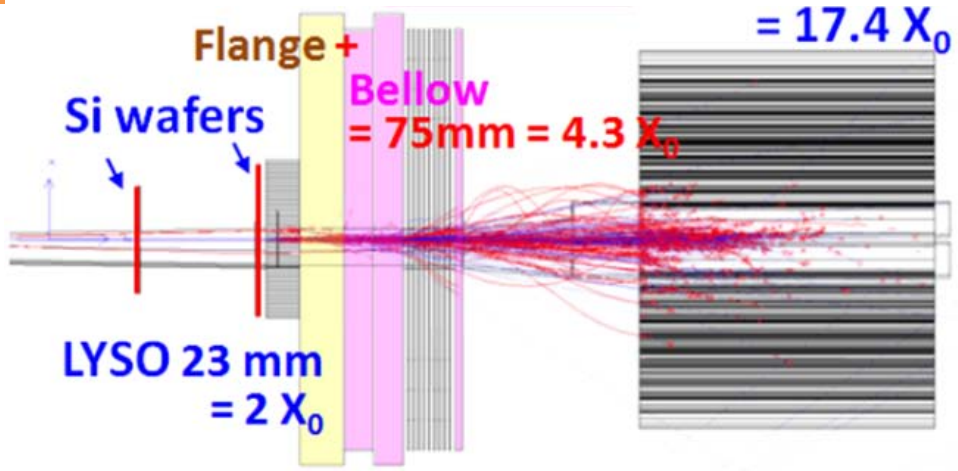
→ ***50 μm*** *on Z eq.* $dr = \delta z \times \vartheta$ = ***1 μm***

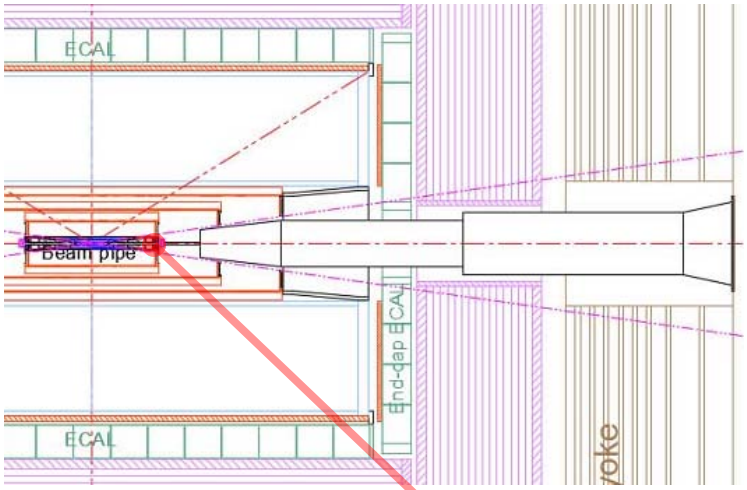
Luminosity systematics

due to events in/out fiducial edge

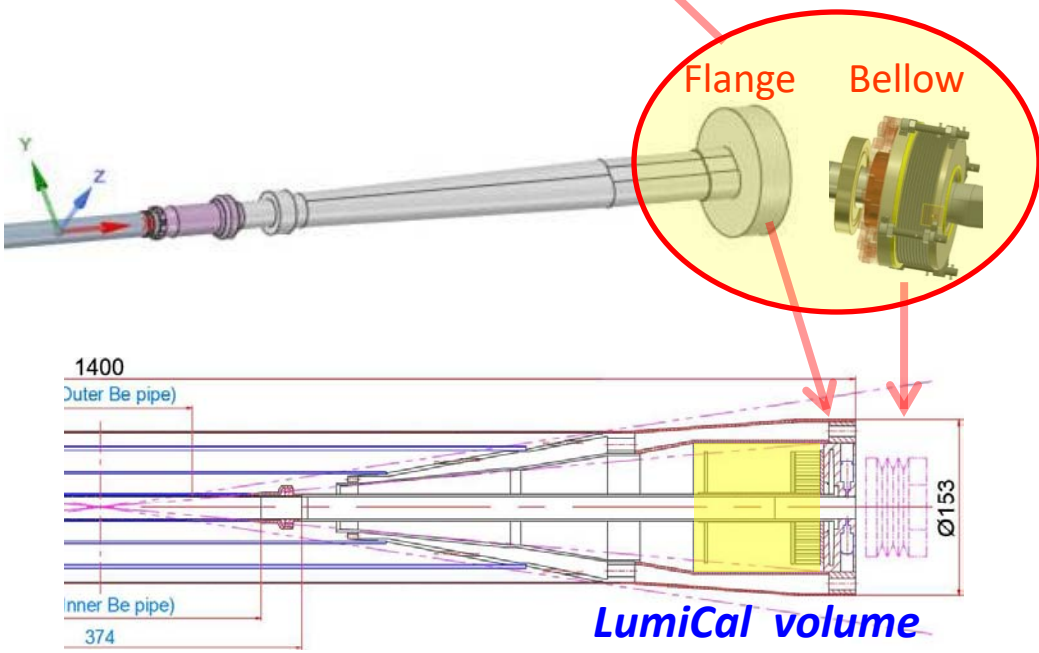
➔ ***offset on the mean of*** θ_{min}

CEPC LumiCal design





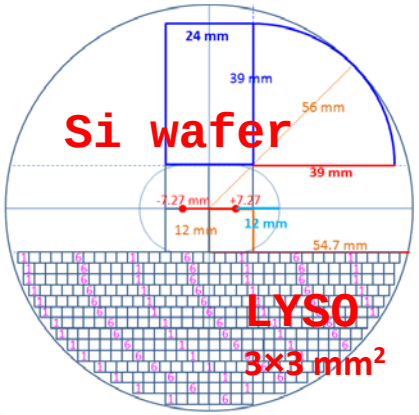
- ***before Flange*** z = 560~700 mm
  - **Low-mass window**: **Be 1mm thick** traversing @22 mRad traversing L= 45 mm, **= 0.13 X_0 (Be), 0.50 X_0 (Al)**
  - **Two Si-wafers** for $e^{\pm}$ impact θ
  - **2X_0 LYSO** = 23 mm
- ***behind Bellow*** z= 900~1100 mm
  - **Flange+Bellow : ~60 mm, 4.3 X_0**
  - **17.4 X_0 LYSO 200 mm**

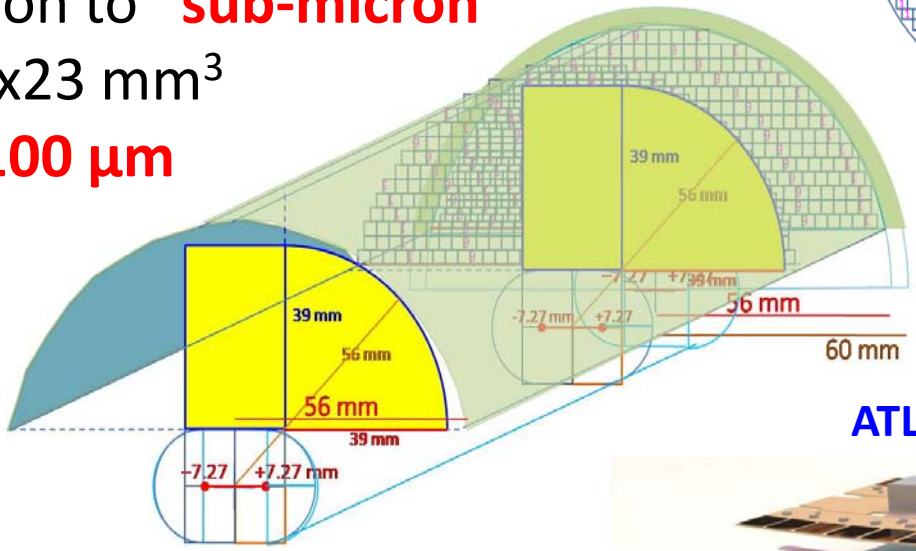


1. LumiCal assembly

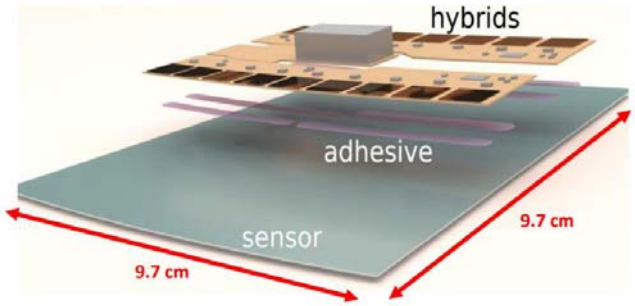
Module before flange

- **Dimension:** 12 cm wide, 4cm high, 12 cm long
- **Two Si wafers** (Strip or AC-LGAD) for $e^{\pm}$ impact θ
  100% detection efficiency,
  align Si wafer position to **sub-micron**
- **$2X_0$ LYSO bars:** 3x3x23 mm^3
  align LYSO bar to **100 µm**





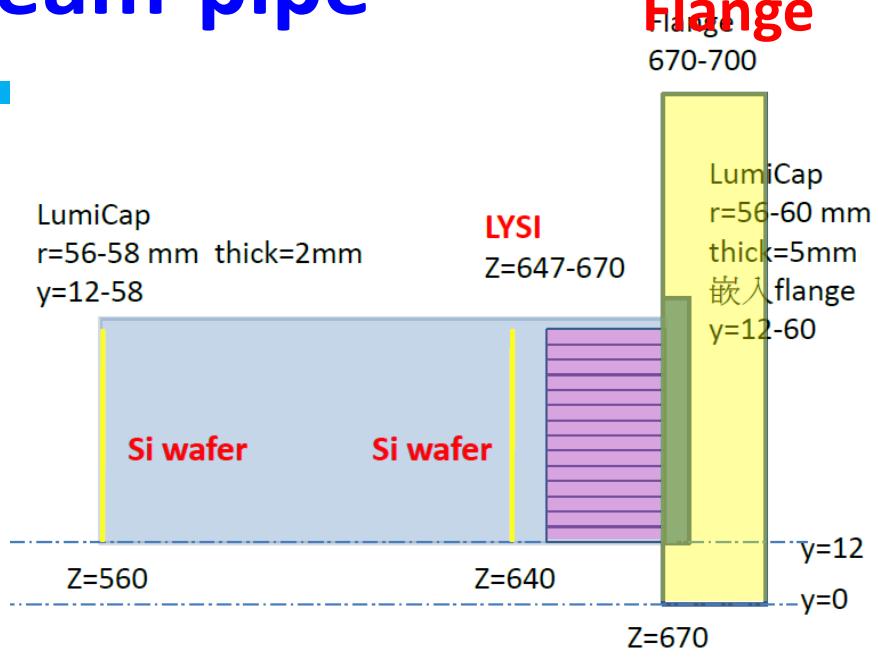
ATLAS ITk P2 wafer

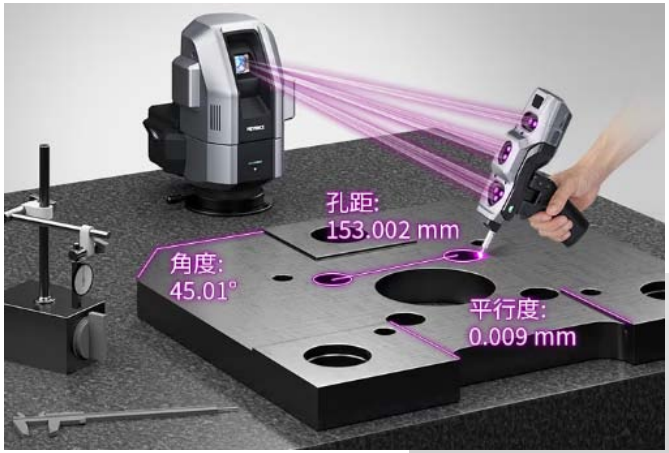


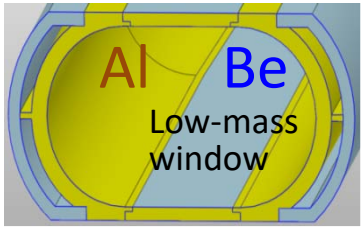
2. Mount LumiCal on beam-pipe

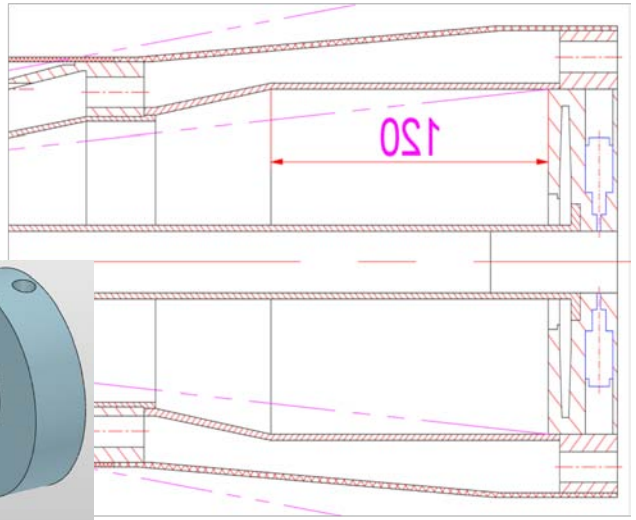
Module before flange

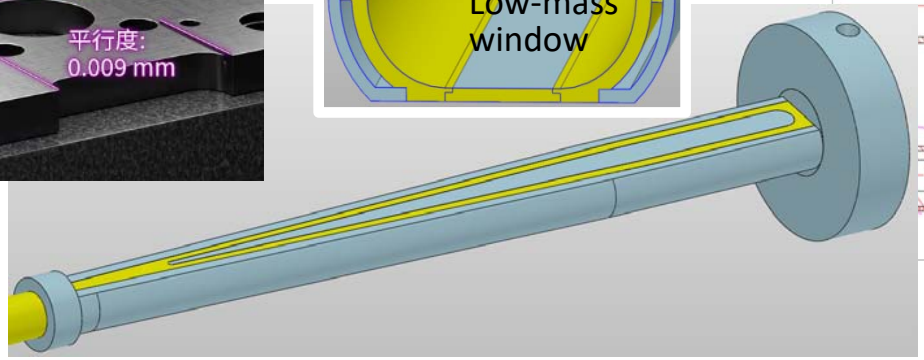
- **Reference points:** **beampipe center**
- **Survey:**
  Si wafer edge to **sub-micron**
  LYSO bar corners to **sub-micron**





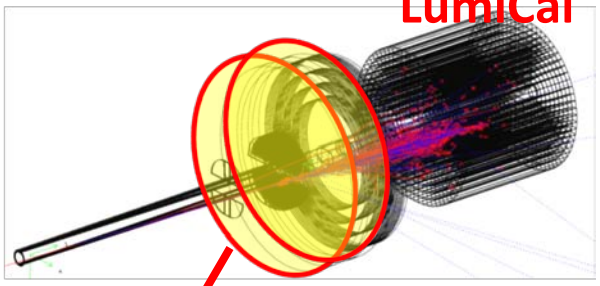


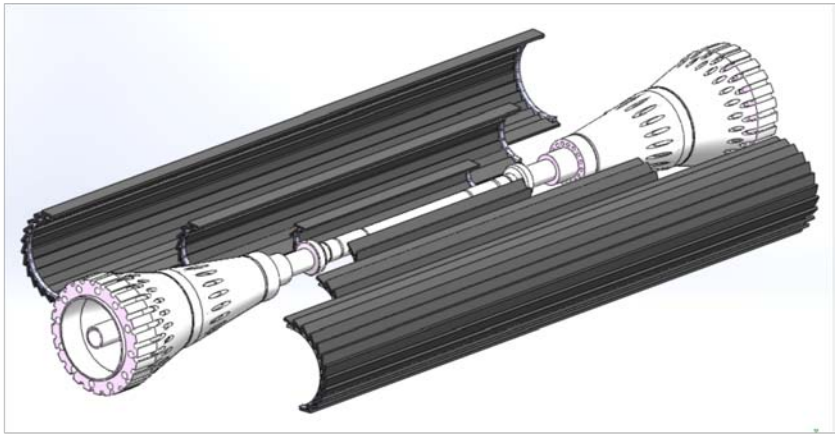


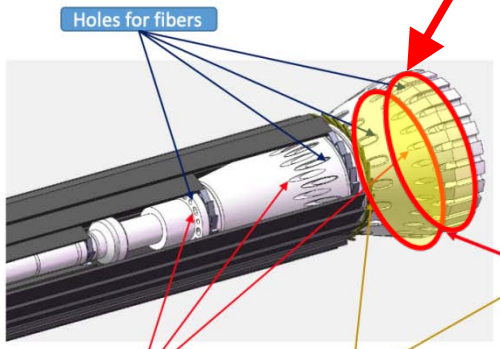


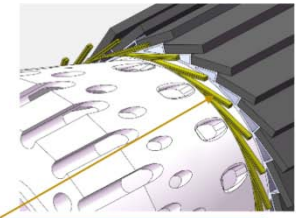
3. Inner beam-pipe assembly

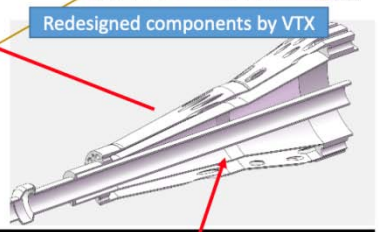
- Install LumiCal before Pixel
- Space clearance and access to LumiCal



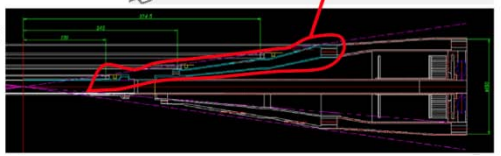


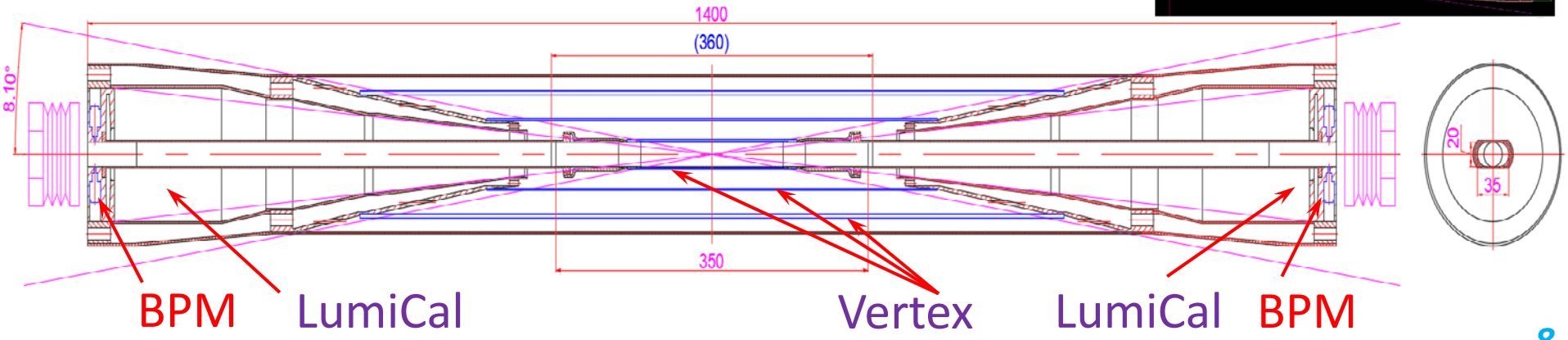






According to the current plan, assuming the flex will be switched to fiber where beyond and near the end of the ladder.





4. Beampipe install, to Quad-pole magnet

Beam-pipe installation

- Insert beam-pipe inside ITk
- Align in quad-pole magnet
- Bellow remote lock-up

Position uncertainties

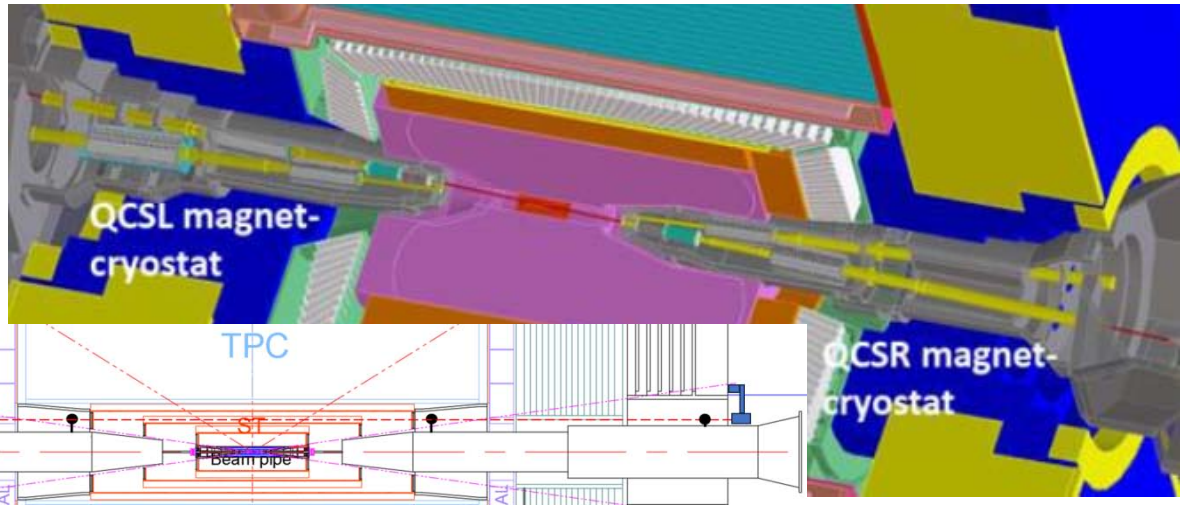
- **± z Flanges**: (δx, δy, δz)
  → LumiCal offset
- **Interaction Point**: (δx_0, δy_0, δz_0)
  → beam line to Q-pole center

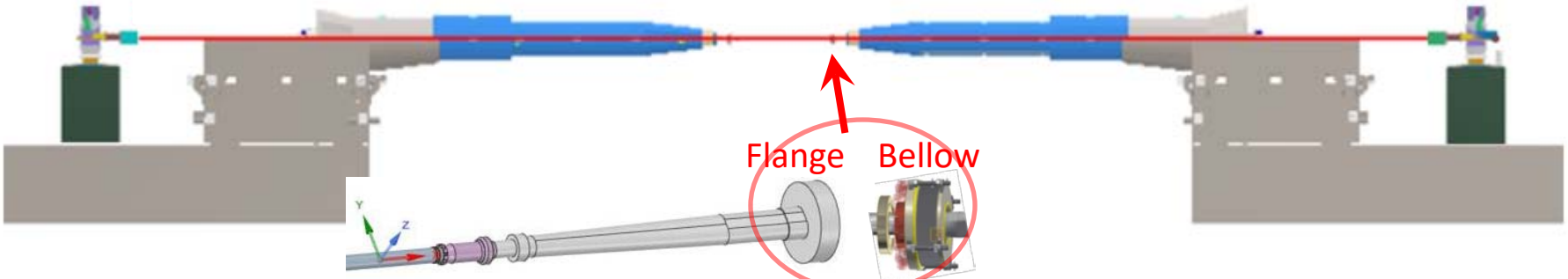
LumiCal position

1 µRad precision:

➔ δr = 1 µm

δz = 50 µm



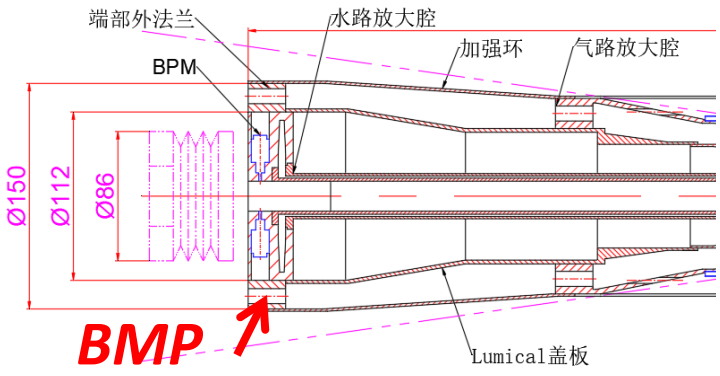


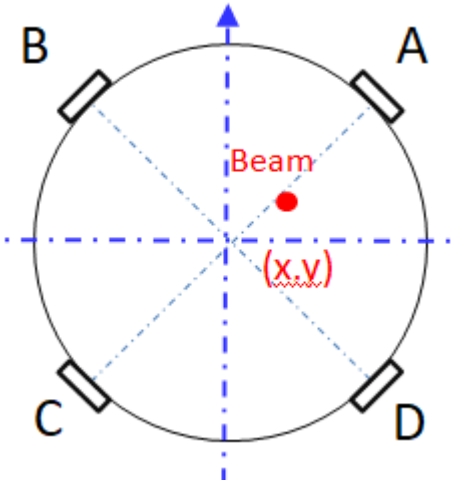
LumiCal survey/monitoring, Beam position

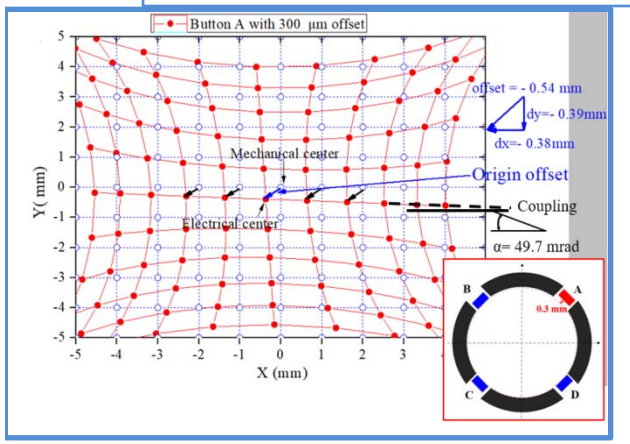
Survey monitoring

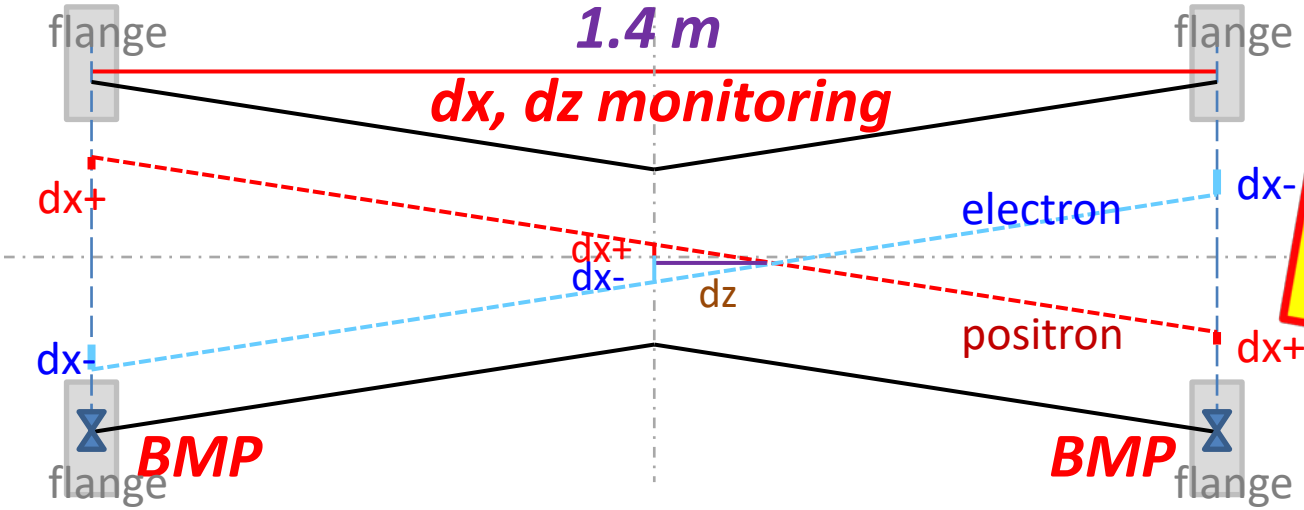
- Beam monitoring Probe ***BPM,*** on beam line crossing IP
- Position monitoring, Flange dx,dy ~1 ***μm***, dz~ ***50 μm***

CEPC WS2023, J. He









LumiCal 挑战
监测位置
1. 法藍 dx,dy 1 μm,
dz 50 μm
2. 电子束流 dx,dy 1 μm

LumiCal survey/monitoring, to 1 µRad

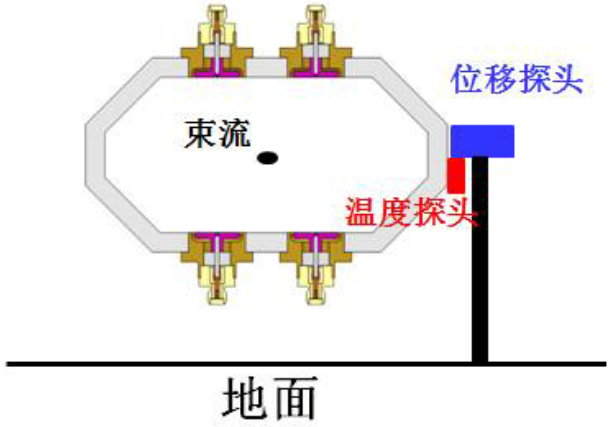
束流位置测量

随艳峰、何 俊
高能所加速器中心束测组
2022-05-06

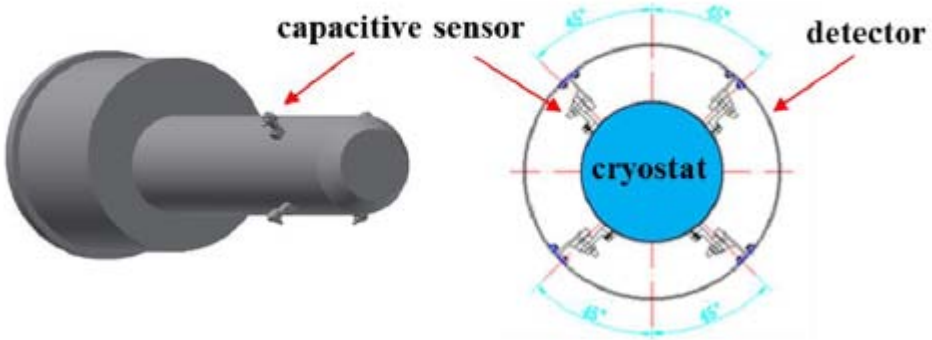
MDI 准直方案初步设计
王小龙 8-23

微米级精度

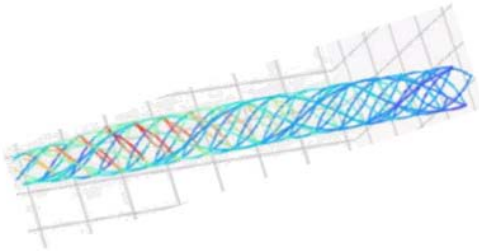
- 温度引起的形变，改变电中心、机械中心

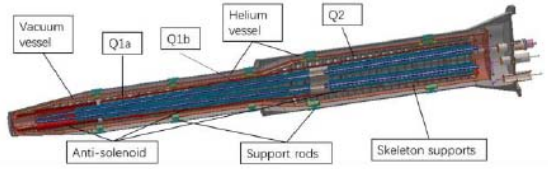


电容传感器监测恒温器端头位置



分布式光纤监测恒温器变形（FCC）





LumiCal theta precision, 1 µRad

Position systematics :

- **IP position:** e^+e^- IP(x_0,y_0,z_0)

  bunch spread $\sigma_x\ \sigma_y\ \sigma_z$ = 6 µm, 35 nm, 9 mm

  simulate $Z \rightarrow e^+, e^-$ at ϑ=30 mRad

  at @z=560mm $\sigma(\vartheta)$ = 24 µRad

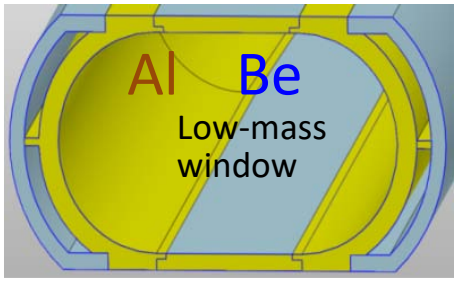
  back-to-back $\sigma(\Omega)$ = 21 µRad

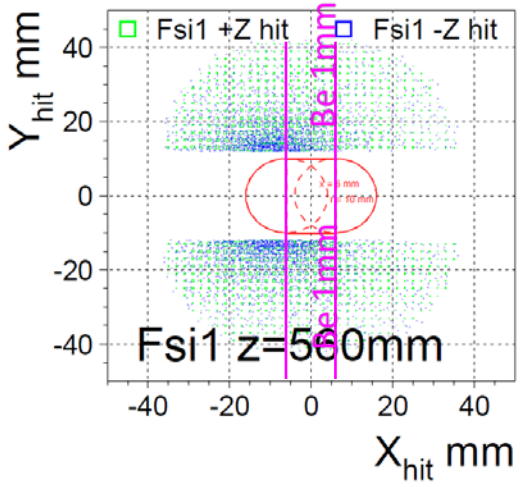
- **LumiCal Si-wafer**:

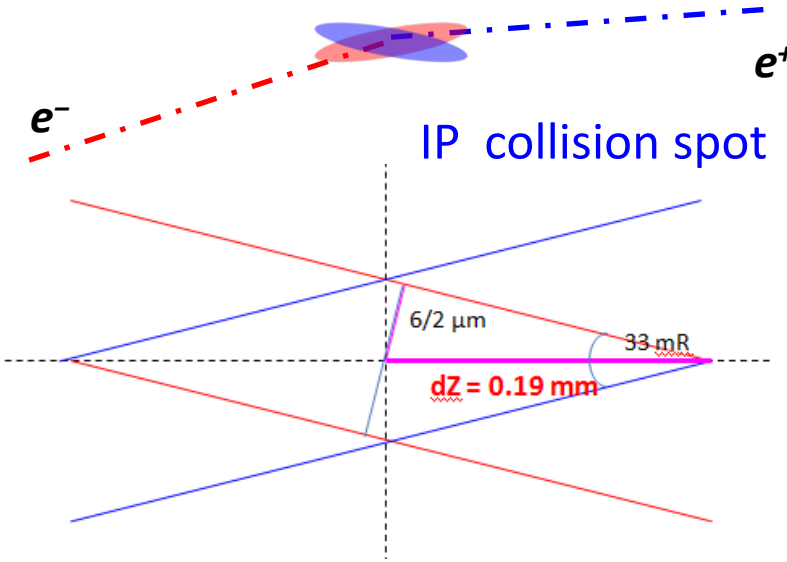
  50 GeV muon from IP,

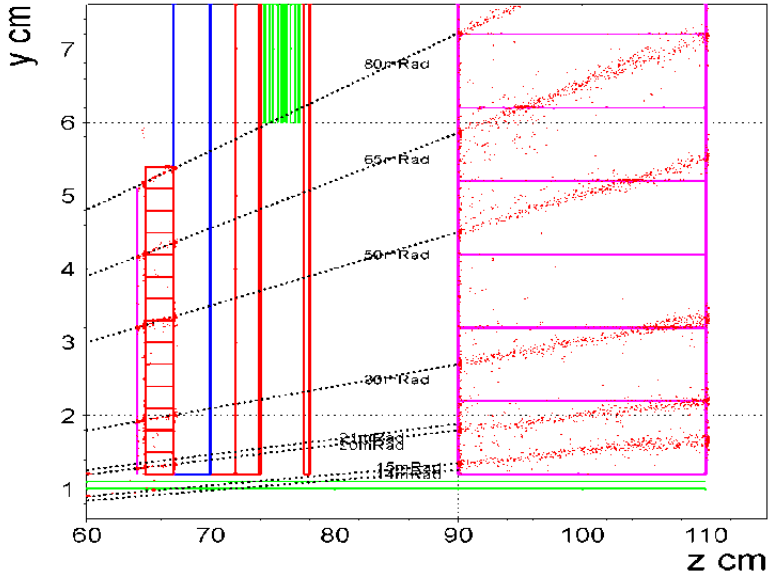
  multiple scattering through *1mm Be* pipe

  σ_ϑ ~50 µRad





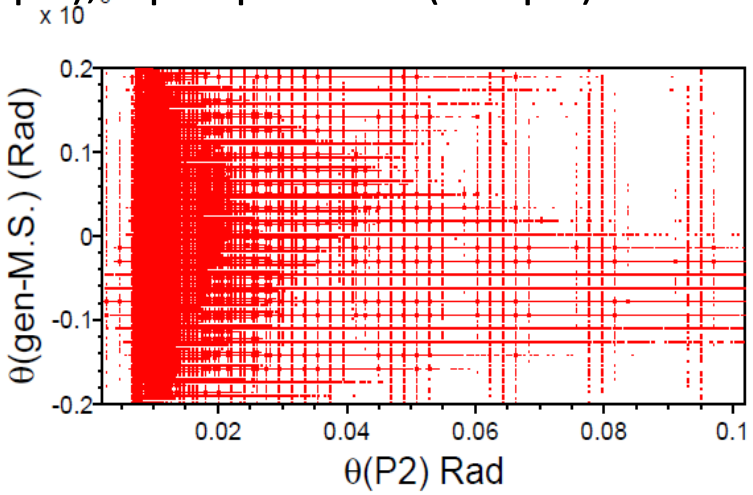


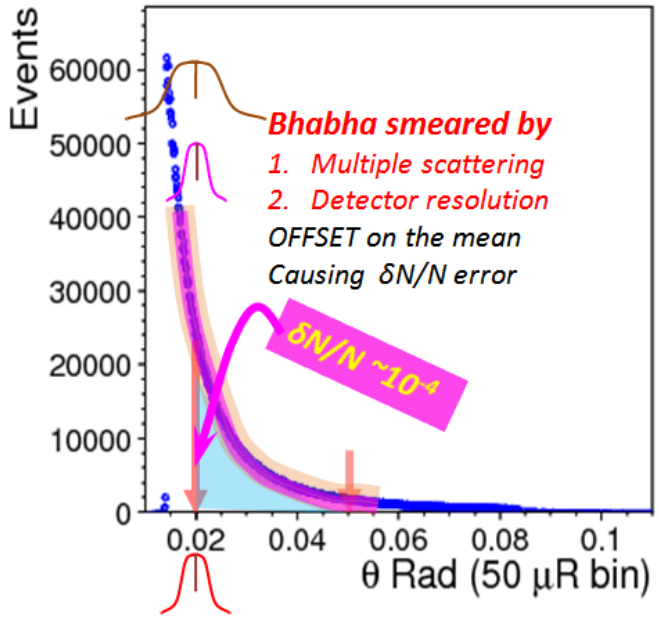


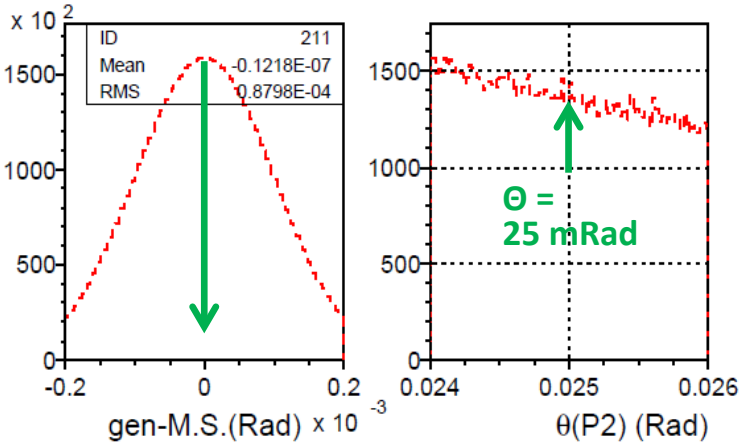
LumiCal 10^{-4} systematics

1. **BHLUMI** smear θ', ϕ' of scattered e^+, e^-
   Multi. Scatt. 100 µRad θ'= θ · Gauss(100µR), ϕ'= ϕ · Gauss(100µR)
2. **δN/N systematics**:
   δN = #event deviation due to M.S.
   M.S is Gaussian, Symmetric
   at **θ_{min}= 25 mRad, slope of Bbhabha**
   in neiboring 100 µRad bins to 25mR

δN(@25mR)/N(25-80 mR) <10^{-4}







10^{-4} is determined by survey of the mean position

Summary

- **LumiCal** can be constructed for **1 *μRad precision***
- **Multiple scattering** to fiducial acceptance
  error-on-mean systematics **< 10^{-4}**
- **Major systematic uncertainties** to LumiCal/Luminosity
  required for **dr ~1 *μm, dz ~50 μm***
  1. ***survey/monitoring precision of LumiCal position***
  2. ***beam, IP position***