LumiCal
with the race-track beampipe

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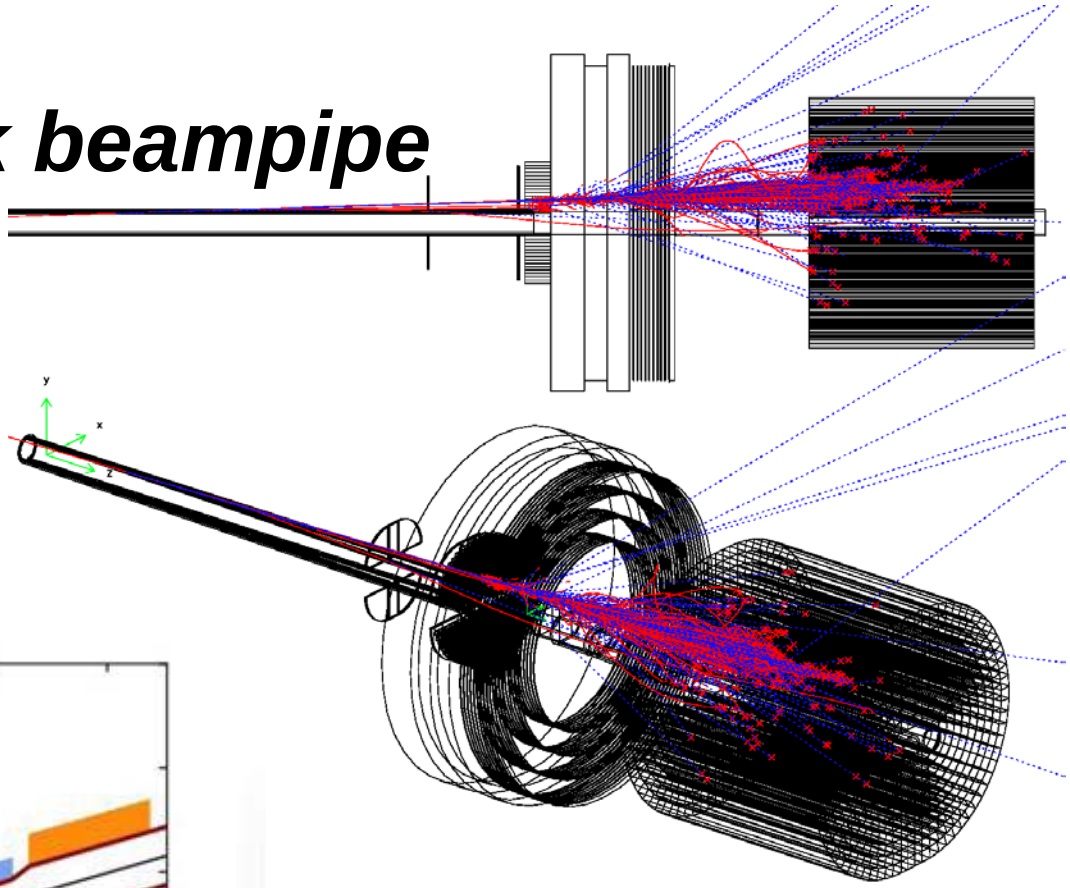
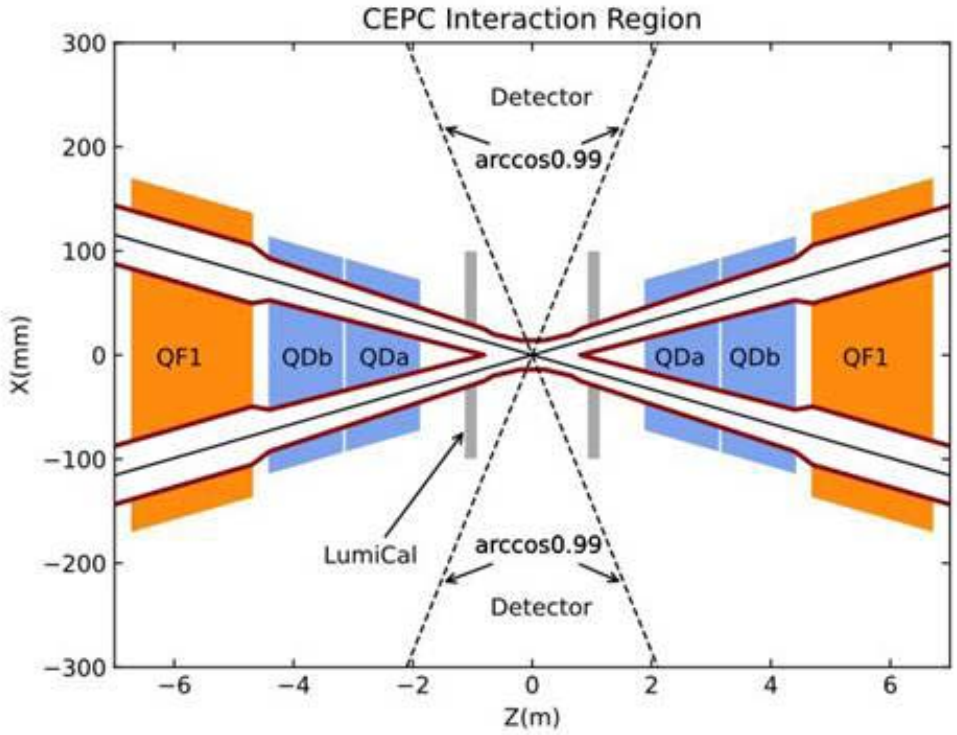




https://indico.ph.ed.ac.uk/event/259/

Introduction

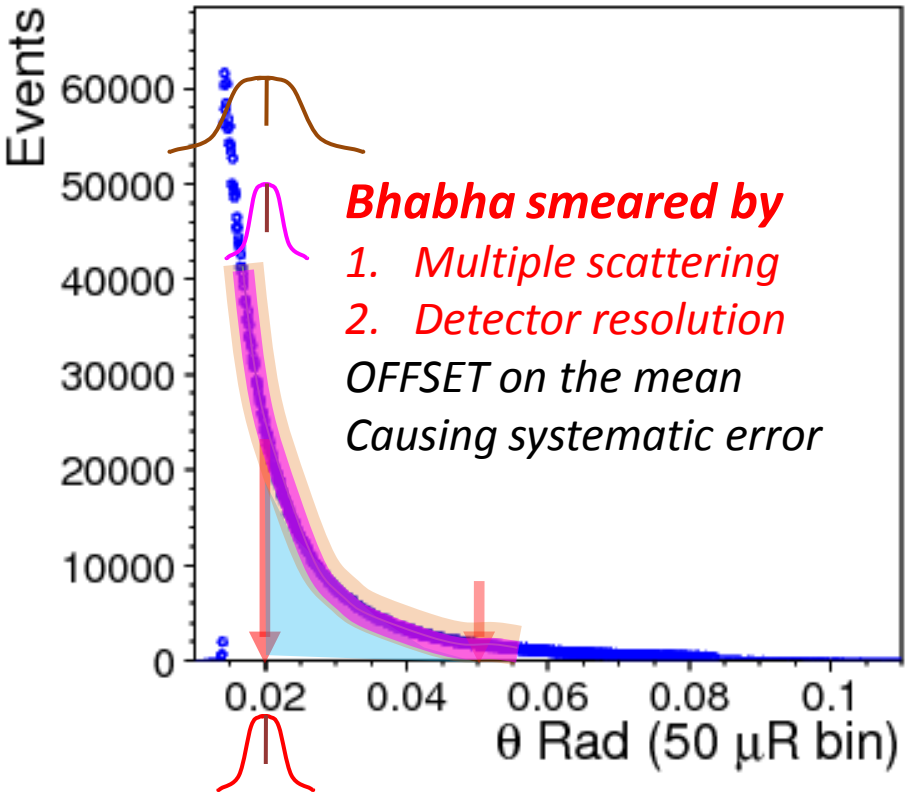
LumiCal to 10^{-4} Luminosity

ø 20 mm Racetrack beampipe

- Bhabha fiducial large X-section w. **lower θ_{min}**
- **IP** tracking, **1 mm Be** beampipe window
- error on-mean of **θ_{min} → 10^{-4}**

LumiCal optimization:

- before Flange :
  Si wafer + $2X_0$ LYSO
- after Bellow ($4X_0$):
  $17X_0$ LYSO for $e^{\pm}$ energy

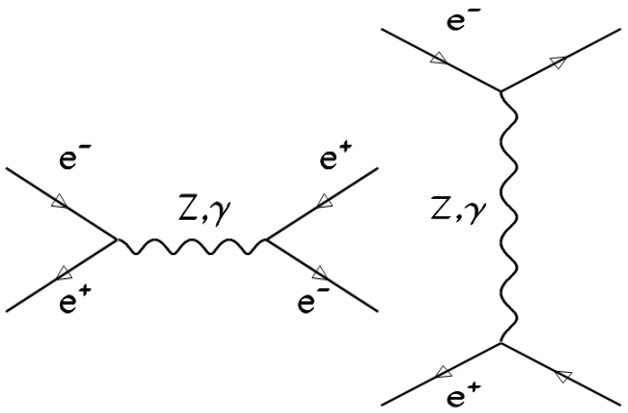


Bhabha e^+e^- Elastic Scattering

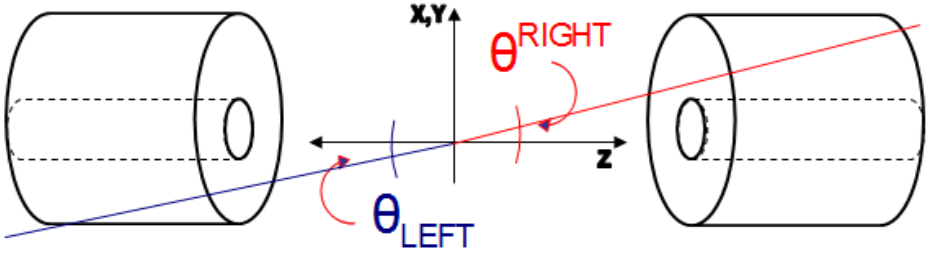
QED Bhabha BHLUMI
Cross section at CEPC

Luminosity by Bhabha elastic scattering

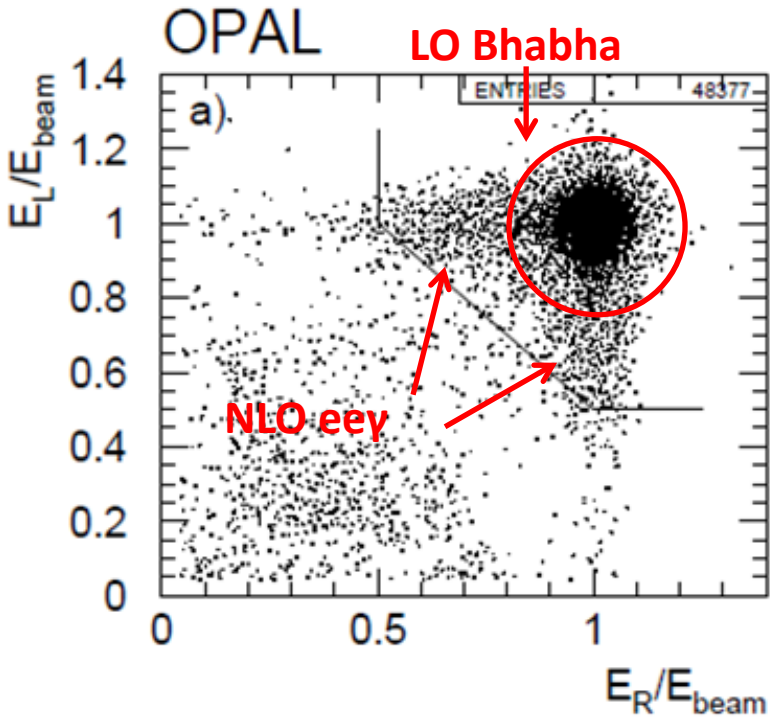
- ***Physics events, e.g. Z-pole,***
  $N = \sigma \cdot \int L$ ***L: Luminosity of e^+e^- collisions***
- ***Luminosity* by counting Bhabha events**
  $e^+e^- \rightarrow e^+e^-(\gamma)$ QED *theo. precision < 0.1%*
  1. ***a pair of electrons,*** $E(e^{\pm}) = E_{beam}$ ***back-to-back***
  2. ***precision ϑ of e, e(γ)***
  3. ***within fiducial region***



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



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



Bhabha luminosity precision

Luminosity= counting Bhabha events

In a *fiducial ϑ region*

systematic error :

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

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

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

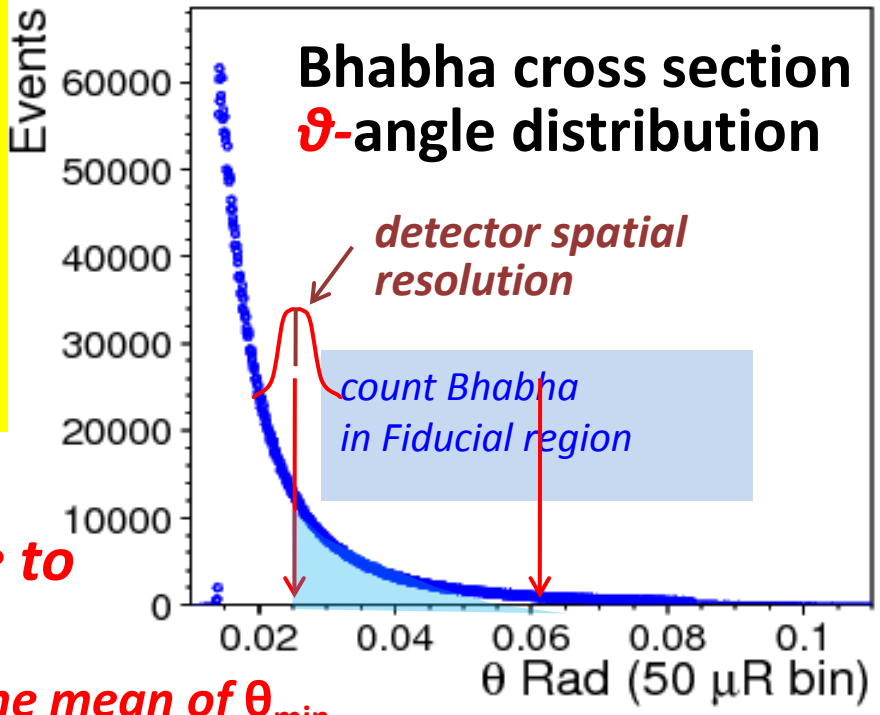
Require $\delta L/L = 10^{-3}$

at **z = ±1 m,** θ_{min} = 20 mRad

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

Error due to offset on Z

→ ***0.5 mm*** *on Z* or $dr = \delta z \times \vartheta$ = ***10 µm***

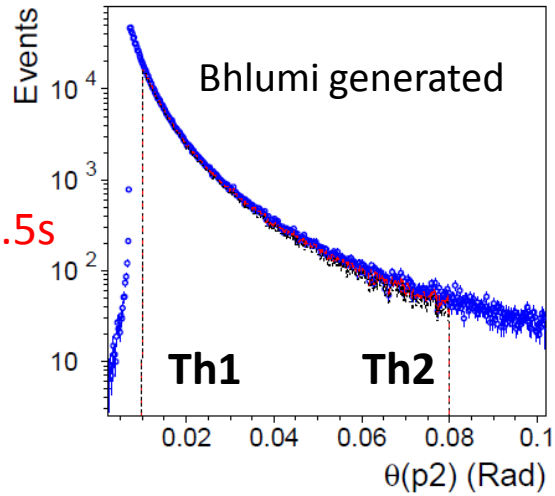


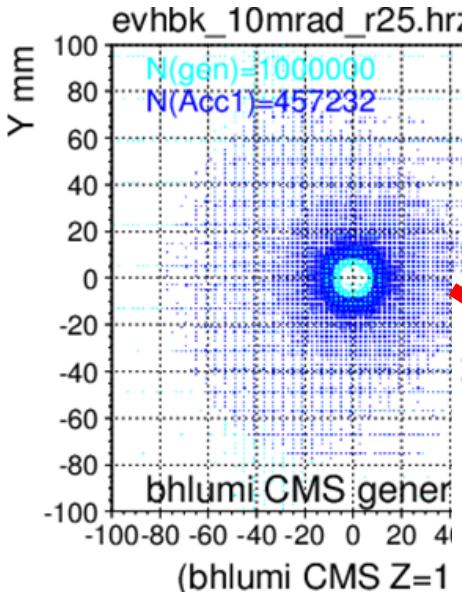
***Luminosity systematics** due to events counted in/miss fiducial region*

➔ *spatial resolution = offset/error on the mean of* θ_{min}

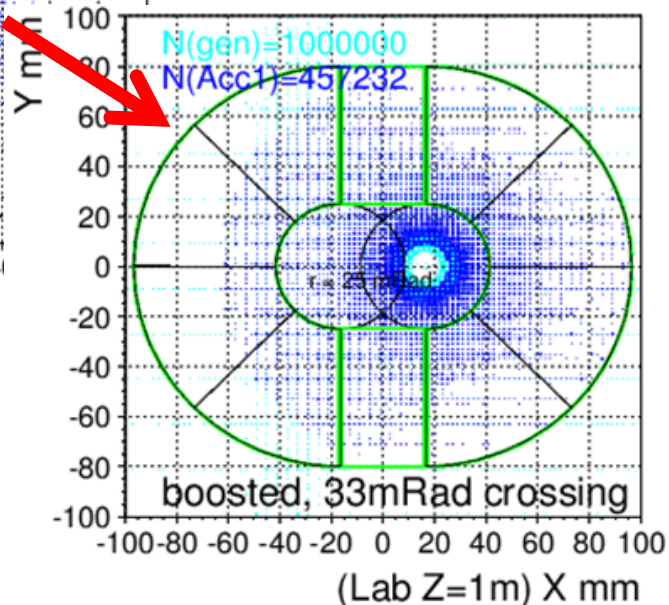
BHLUMI + beam-crossing

1. **BHLUMI** QED 0.06% precision (PLB 450, 262)
   CMS m_Z = 92. 3 GeV**, fiducial region:** Th1<θ<Th2, s'> 0.5s
2. **CEPC boost** : e^+e^- beam crossing, **33 mRad**
3. **X-section** : count events in fiducial region, w.r.t. QED calculation

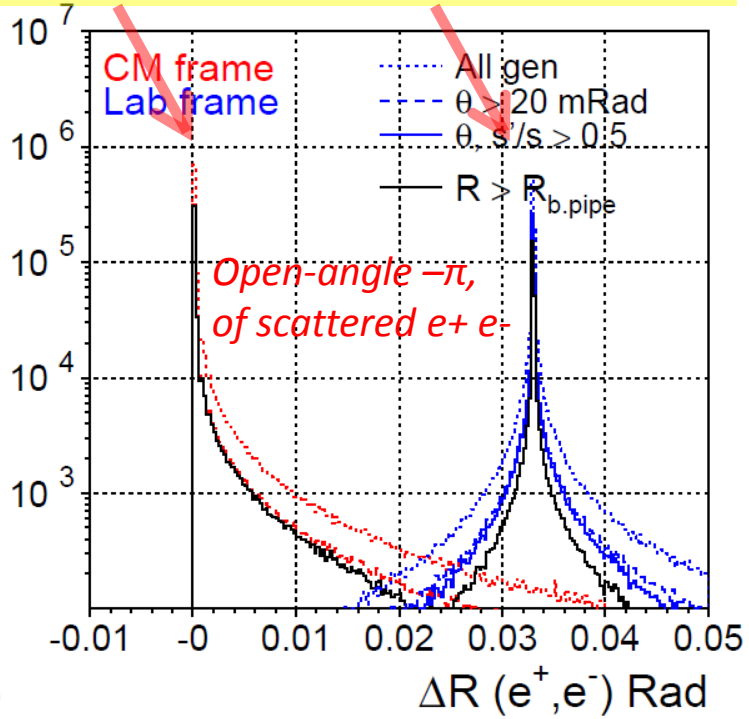




Boost +x,
33 mRad Beam crossing
scattered e+,e-
symm. to outgoing pipe



Multi. Scattering, rad. Bhabha, wider back-back distributions

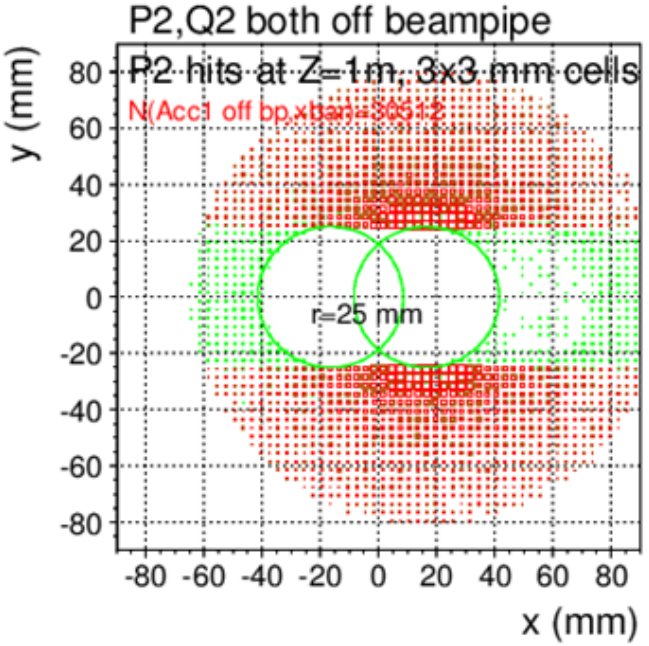


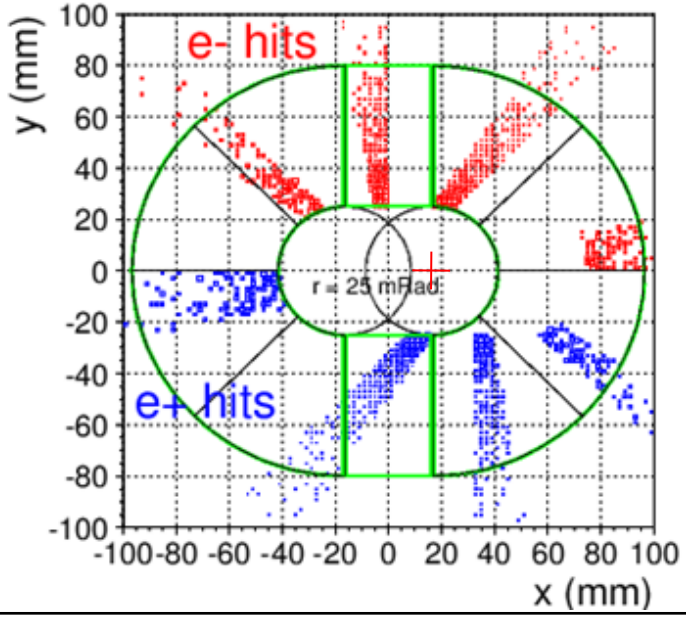
BHLUMI X-section, racetrack @CEPC

Acceptance @ z= 1m r > 25 mm, |y|> 25 mm

e^+, e^- back-to-back
Symmetric to
out-going pipe center

LAB frame
e^+, e^- detected
@ Z=1000 mm





at z = 1000 mm

LAB ONE e^+ or e^- detected		LAB both e^+, e^- detected	
θ>15 mRad	θ>15mR & |y|>15mm	θ>15 mRad	θ>15mR & |y|>15mm
395.3	255.9	257.8	245.9
θ>25 mRad	θ>25mR & |y|>25mm	θ>25 mRad	θ>25mR & |y|>25mm
133.5 nb	81.8 nb	85.4 nb	78.0 nb
θ>30 mRad	θ>30mR & |y|>30mm	θ>30 mRad	θ>30mR & |y|>30mm
87.2	51.8	54.9	49.1

racetrack

CDR

LumiCal to 1 μRad precision

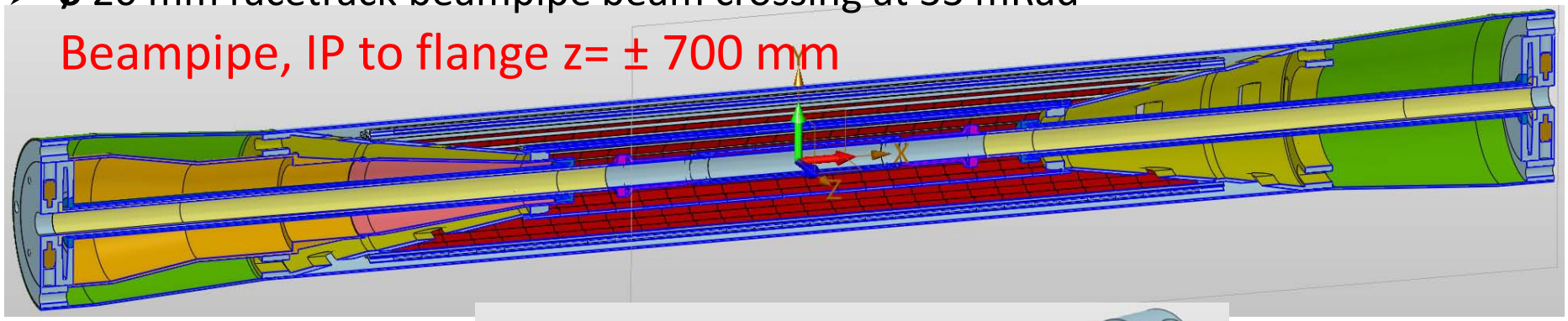
IP beam spot σ_x=6 μm σ_z=9 mm
beampipe multiple scattering

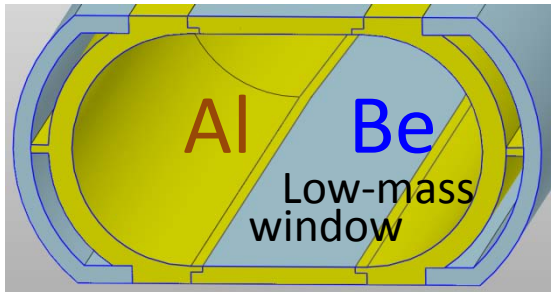
CEPC Accelerator TDR upgrade (J.Gao 3/30)

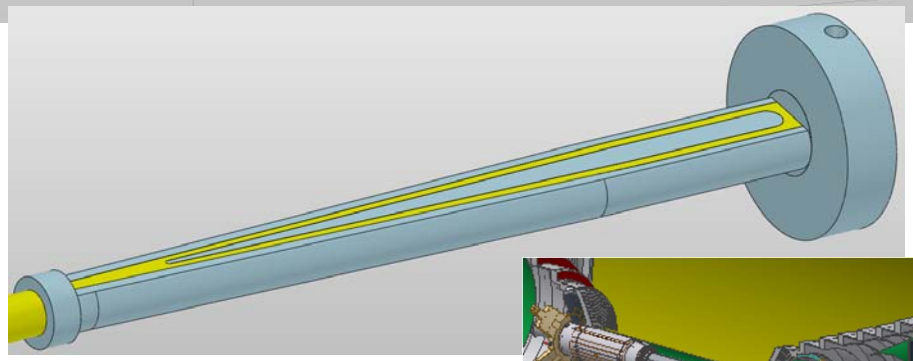
	Higgs	W	Z	ttbar
Bunch spacing [ns]	385	154	15(10% gap)	2640
Bunch population [10^{10}]	14	13.5	14	20
Beam current [mA]	27.8	140.2	1339.2	5.5
Beam size at IP (sx/sy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Luminosity per IP[10^{34}/cm^2/s]	8.3	26.6	191.7	0.8

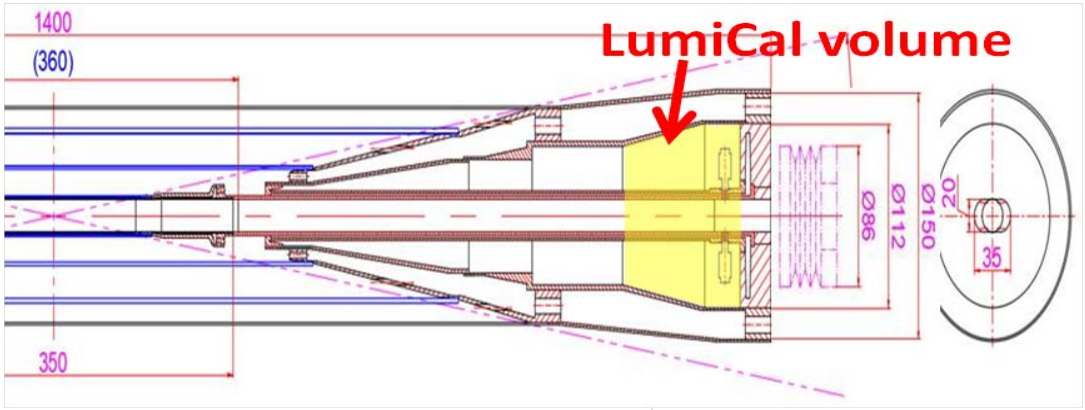
LumiCal in MDI (Machine Detector Interface)

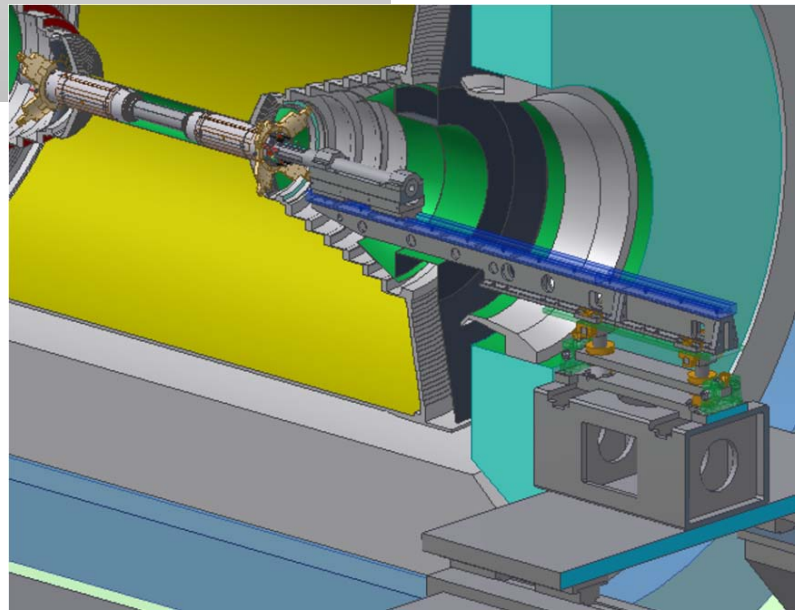
- $2x10^{36}$ luminosity at Z-pole, goal for 10^{-4} systematics
- ø 20 mm racetrack beampipe beam crossing at 33 mRad











MDI configurations to LumiCal

CEPC Accelerator parameters to LumiCal Bhabha detection

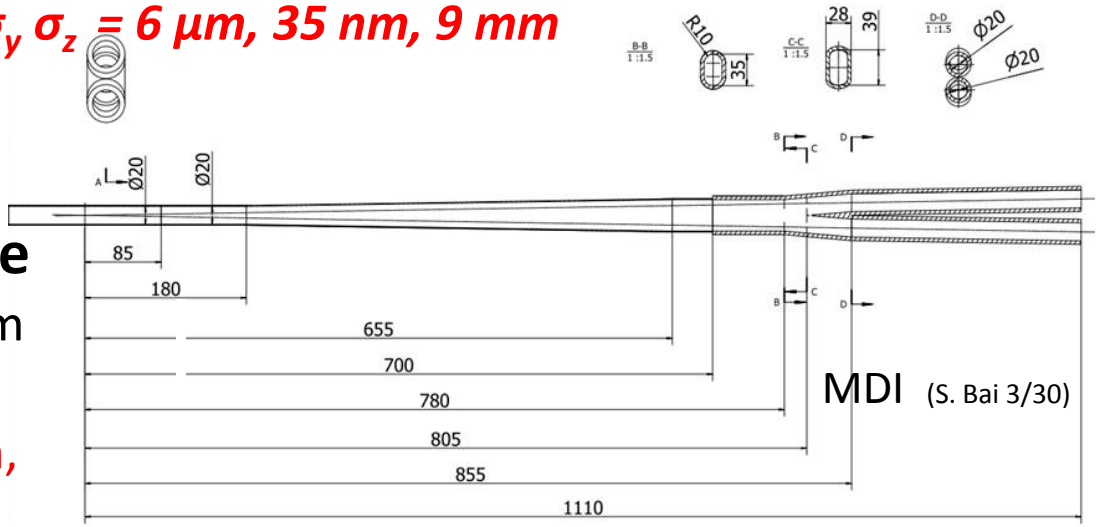
- beam-crossing: **33 mRad**
- IP beam bunch @ Z-pole: $\sigma_x\ \sigma_y\ \sigma_z$ = 6 μm, 35 nm, 9 mm
- Bunch crossing: **23 ns**
- Luminosity: $cm^{-2}s^{-1}$: **2 x 10^{36}**

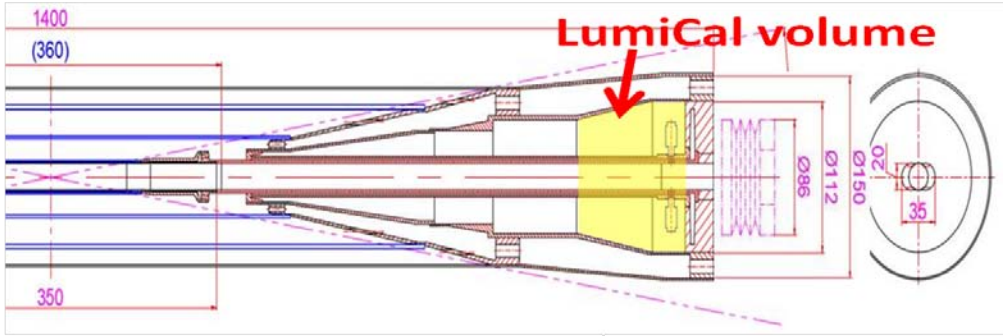
Beam-pipe materials & Space

- **Before Flange:** z = 560~700 mm
  r=10mm, thickness = 1mm
  @20 mRad traversing = 50 mm,
  = 0.14 X_0 (Be), 0.56 X_0 (Al)
- **Two Si-wafers** for $e^{\pm}$ impact θ
- **2X_0 LYSO** = 23 mm

Behind bellow: 900~1100 mm

- **Flange+Bellow : ~60 mm, 6 X_0**
- **17 X_0 LYSO 200 mm**
  for $e^{\pm}$ shower

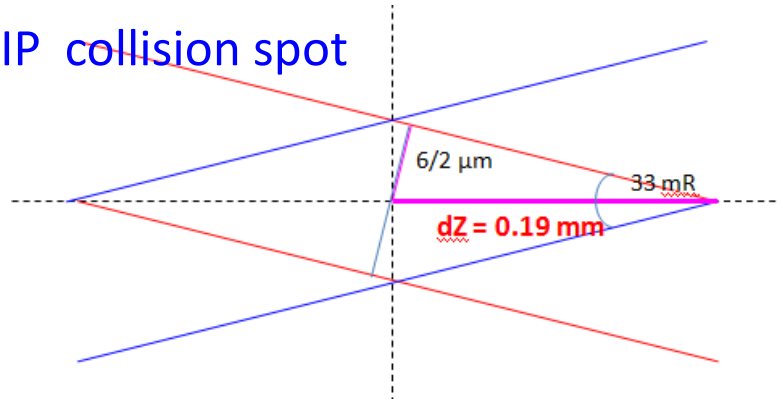




Tracking of IP position

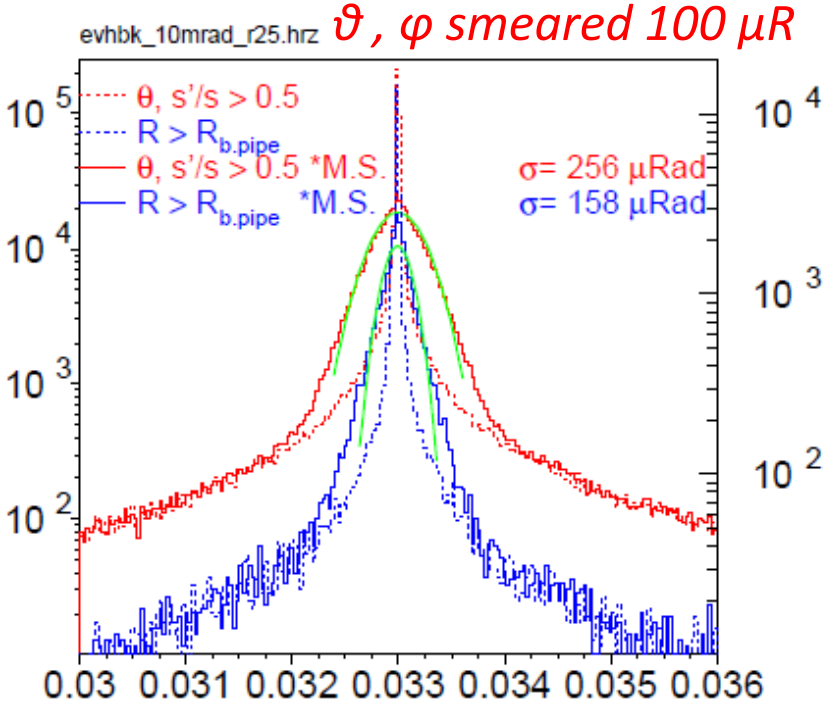
- **Deviation to electron θ by IP spread**
  beam bunch σ_x = 6 μm σ_z = 9 mm
  crossing @ 33 mRad
- **Beam crossing spot : σ_z = 0.38 mm**

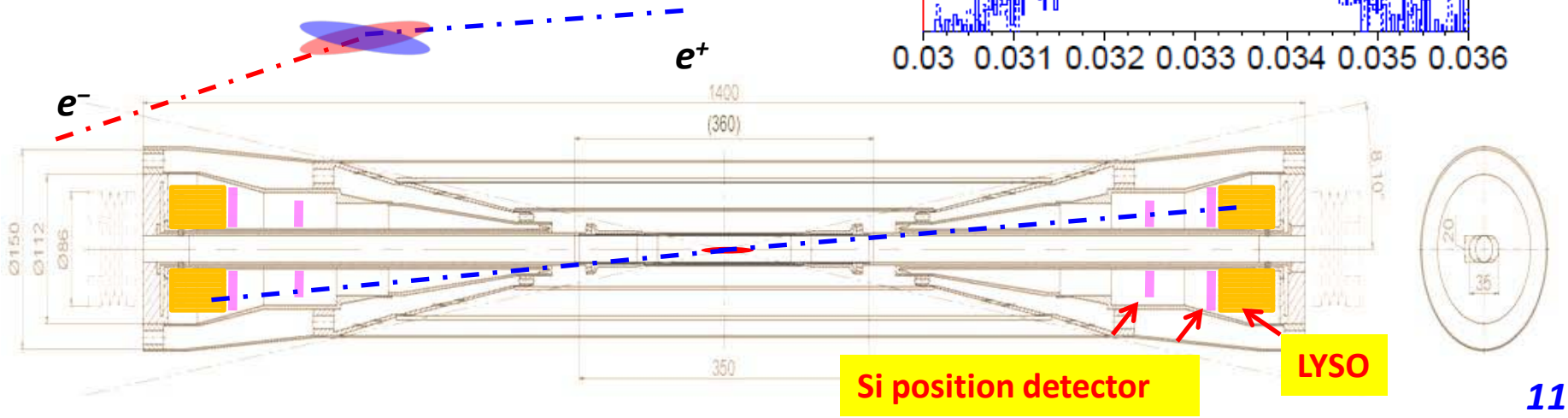
IP collision spot



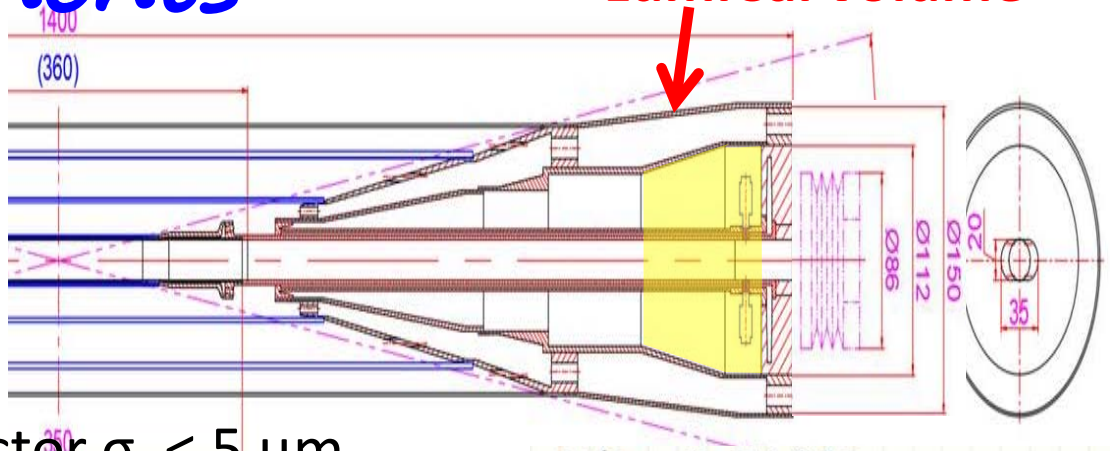
e^+, e^- back-back angle

compare scattered e^+, e^- ϑ , φ smeared 100 μR



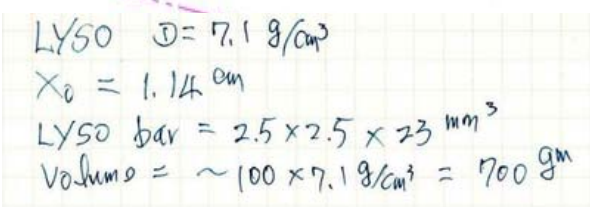


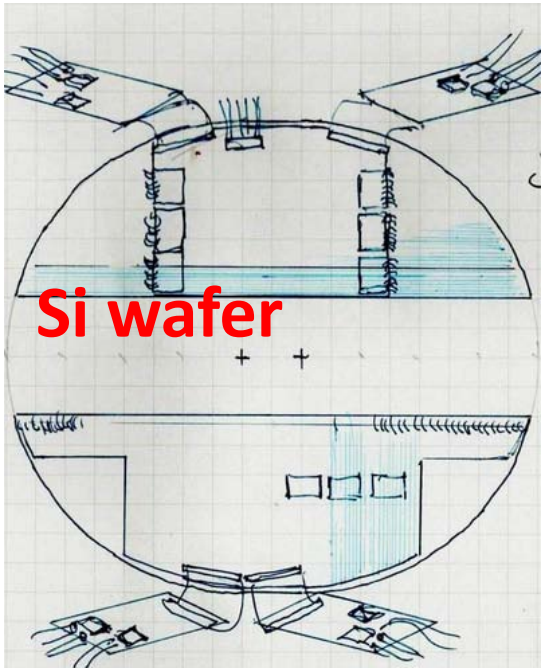
LumiCal components

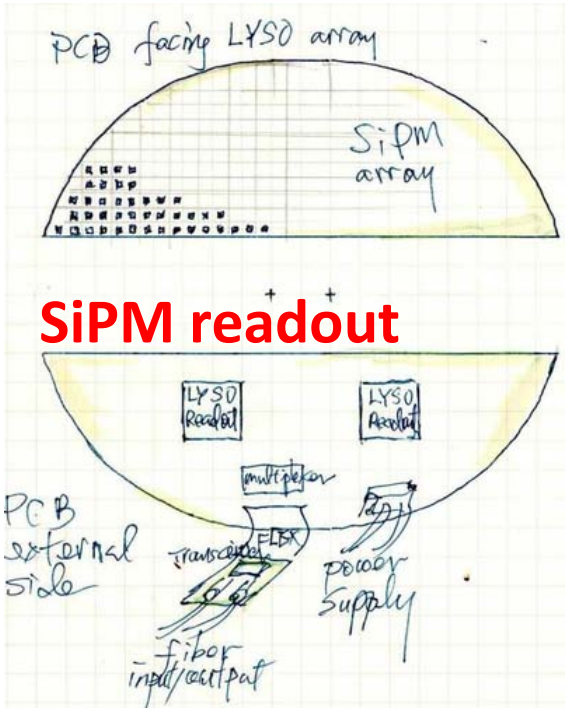


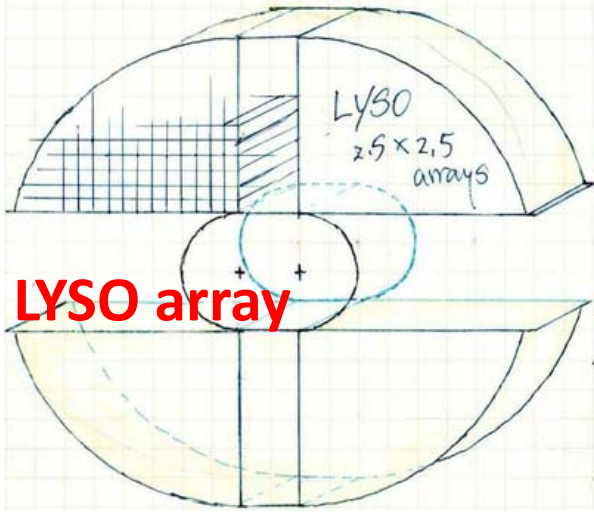
Precision electron θ
e/γ identification

- **Si tracking layers :** detector $\sigma_r < 5$ µm
- **LYSO array, $2X_0$:** 2.5x2.5x23 mm^3









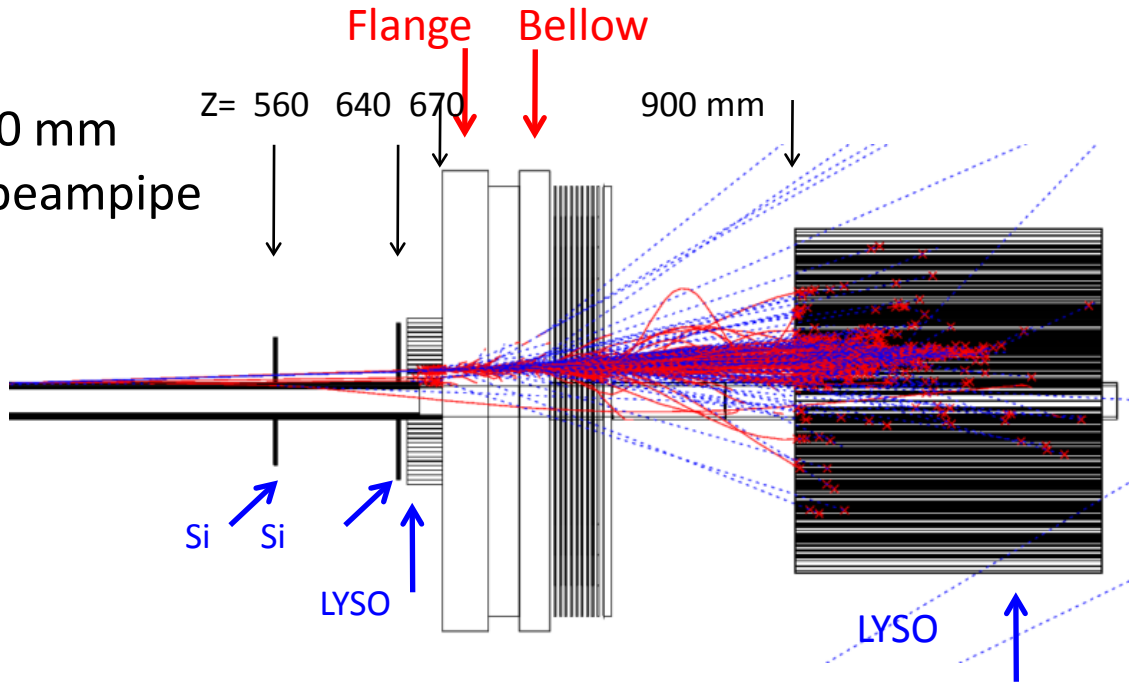
LumiCal on Racetrack beampipe

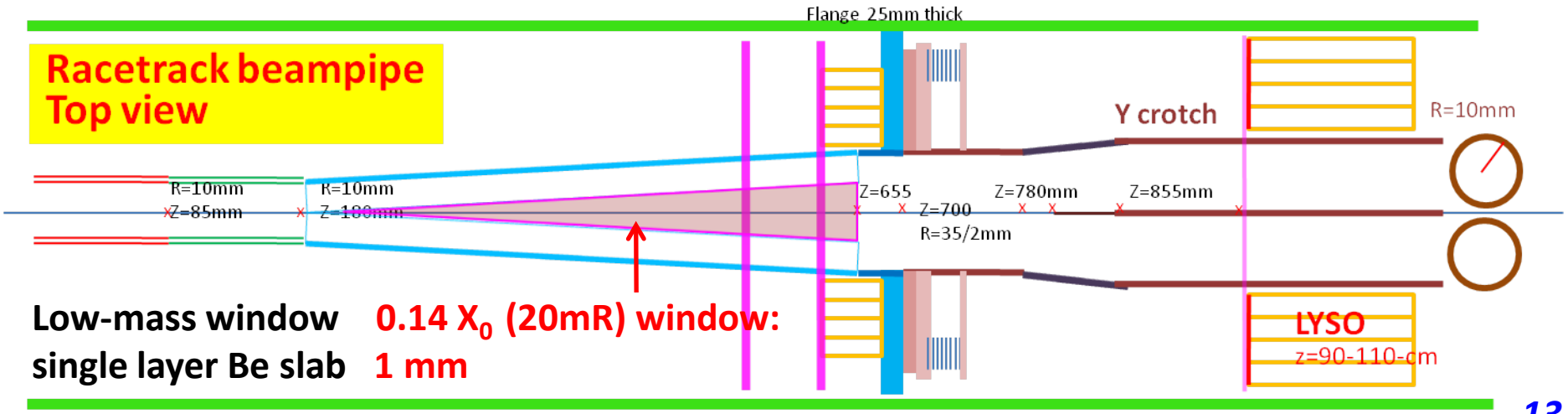
Racetrack beampipe

- beam-pipe r =10 mm, y = ± 10 mm
- boost horizontal, $e^{\pm}$ lost into beampipe

LumiCal

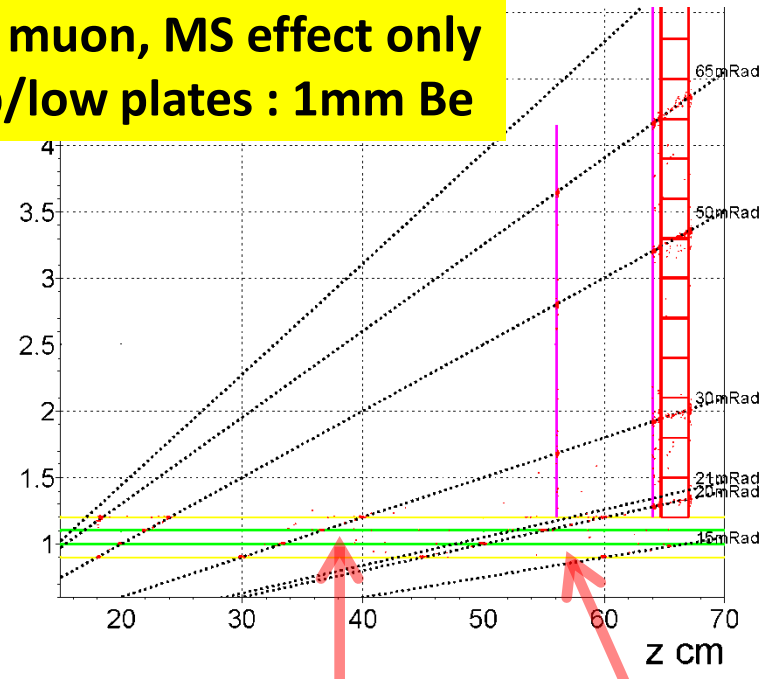
- |y|>15 mm
- **Vertical Si-wafers** :
  $e^{\pm}$ theta tracking
- **LYSO calo** :
  3x3x50 mm^3 bars

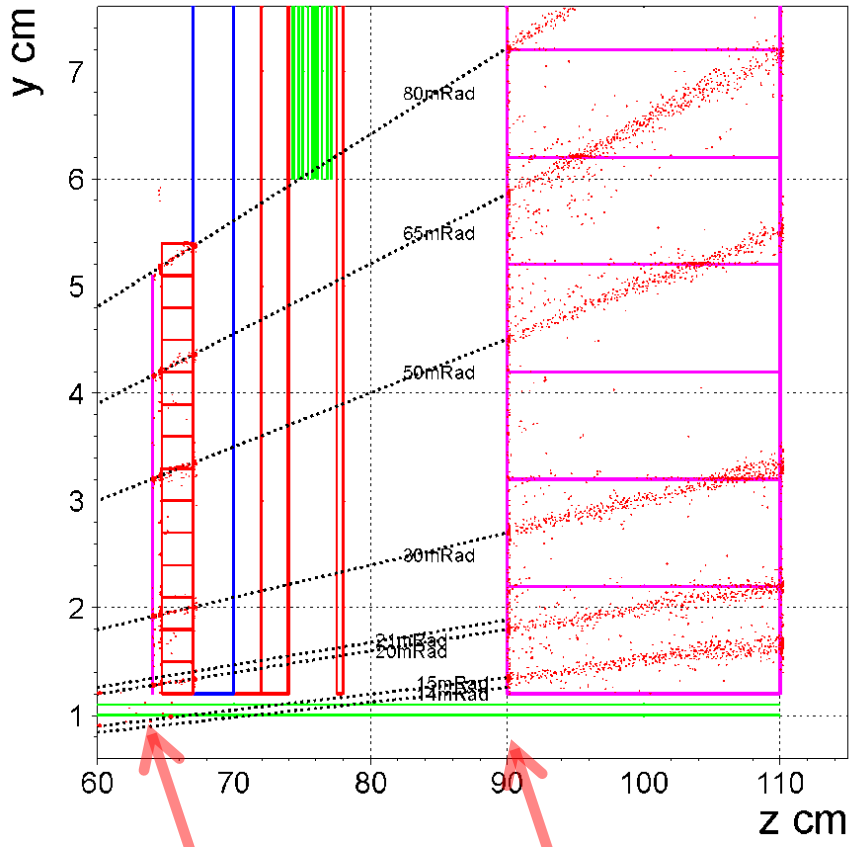




Multiple Scattering

50 GeV muon, MS effect only
pipe up/low plates : 1mm Be





50GeV muon
1mm Be pipe

Exit pipe

Si 1st layer z=560mm

Si 2ND layer z=640mm

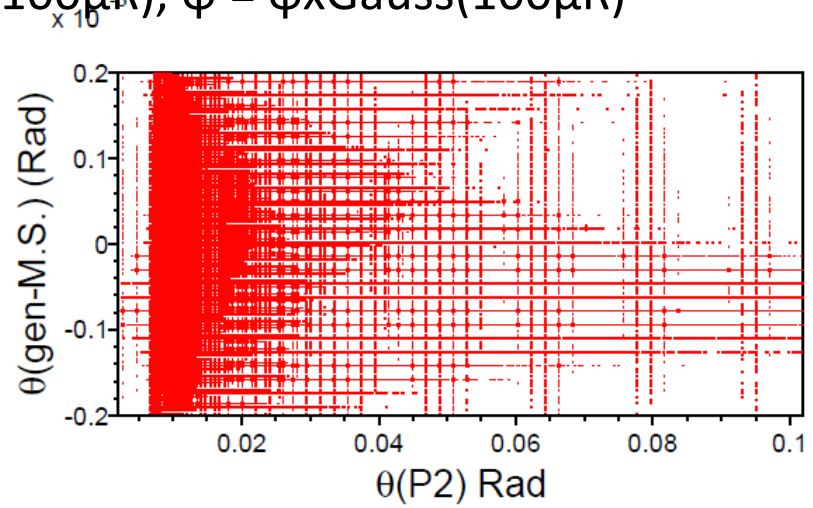
LYSO surface z=900mm

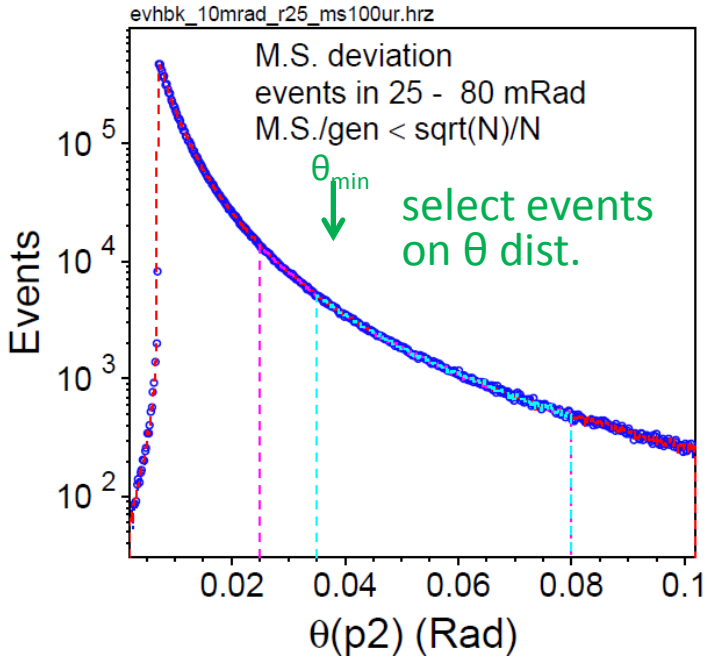
Muon θ mR	L(mm) 1/tanθ	exit pipe dz dθ	Si @560mm dz dθ	Si @640mm dr dθ	LYSO@900 dθ
65	15.4	31 um 11 uR	46 um 80 uR	54 um 85 uR	235 uR
50	20.0	38 um 09 uR	38um 68 uR	47 um 73 uR	235 uR
30	33.3	158 um 13 uR	32 um 56 uR	43 um 68 uR	244 uR
20	50.0	433 um 16 uR		25 um 39 uR	257 uR

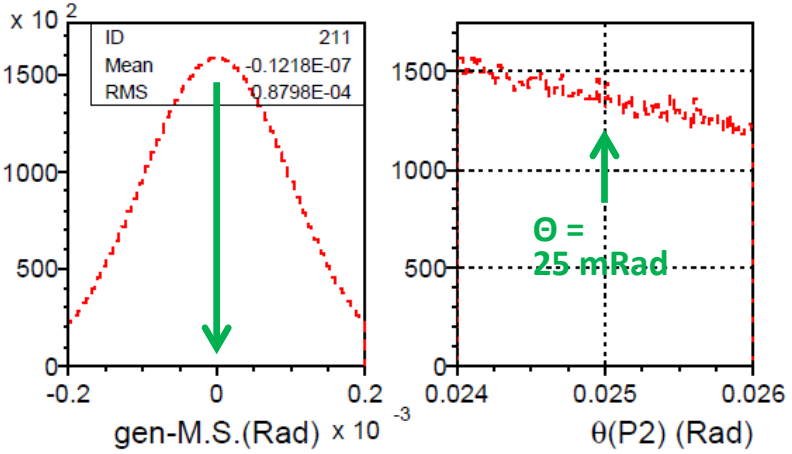
r/z =tan θ

10^{-4} systematics, Multiple scattering

1. **BHLUMI** smear θ', ϕ' of scattered e^+, e^-
   Multi.Scattering 100 µRad θ'= θxGauss(100µR), ϕ'= ϕxGauss(100µR)
2. **δN/N systematics**:
   δN = count 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}





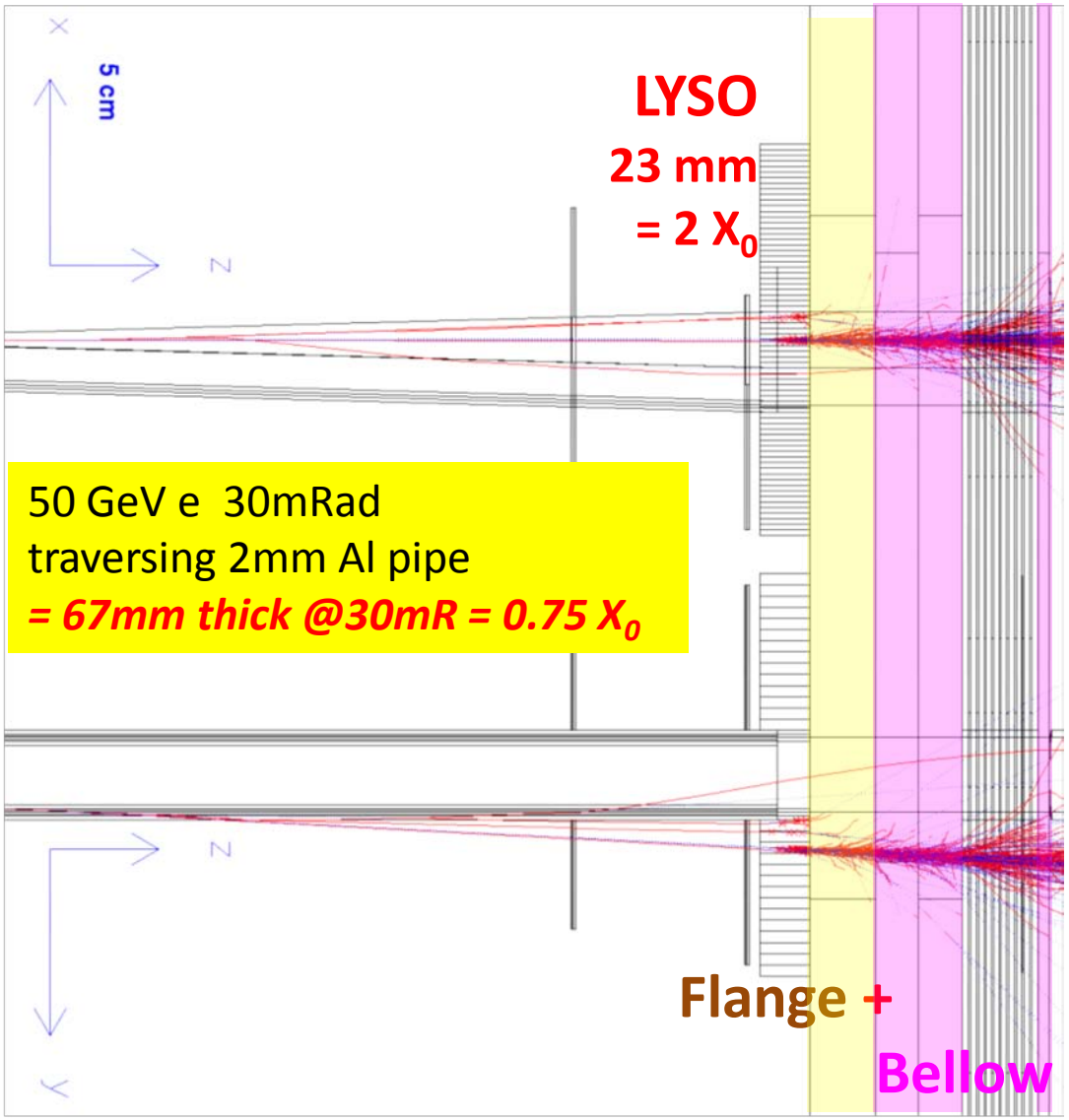


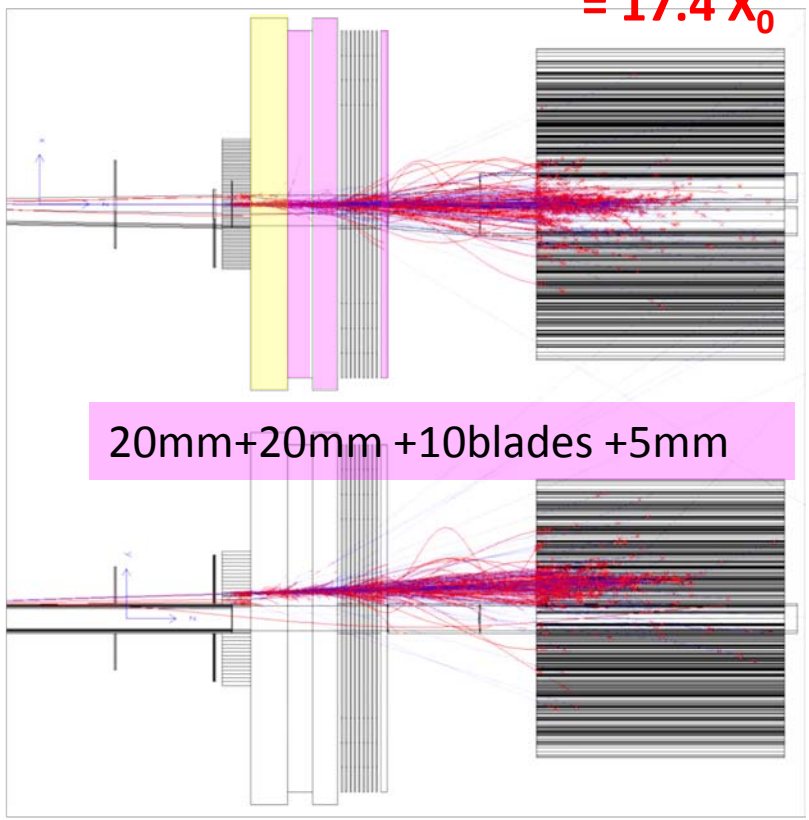
10^{-4} is determined by survey of the mean position

Preshower in beampipe
LumiCal Calorimetry

Secondaries produced in beampipe
e/γ ID in flange LYSO
beam electron by 20 X_0 LYSO

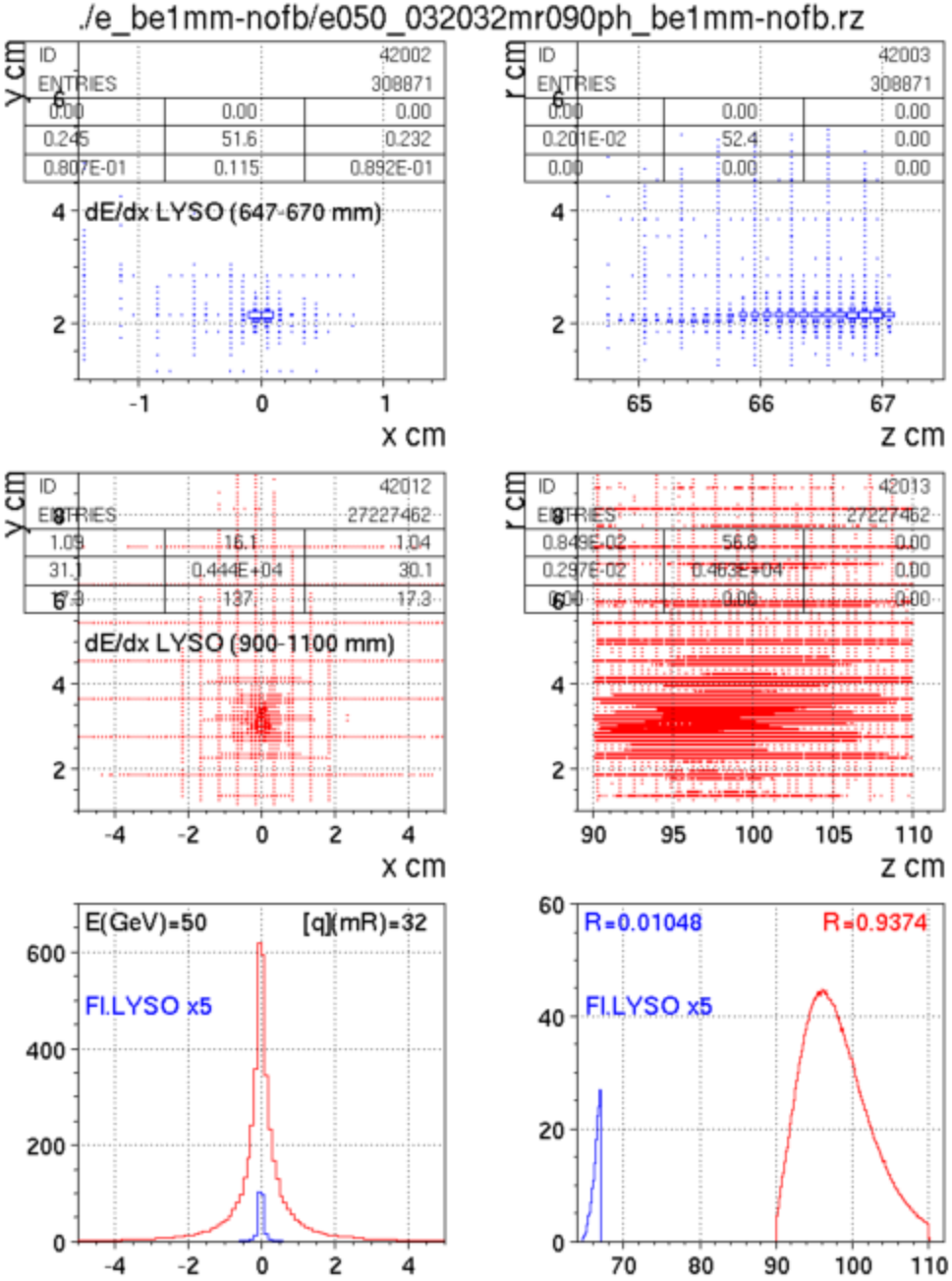
Secondary particles generated in beampipe





Fe $1X_0$=17.6mm

Shower in LYSOs Flange,Bellow absent



50 GeV electron

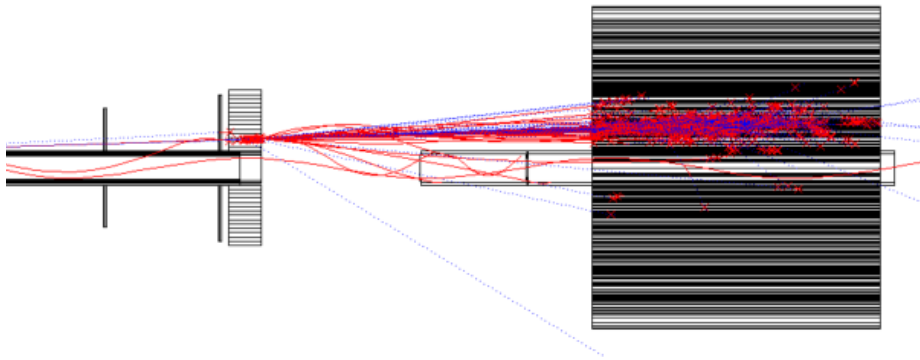
θ = 32 mRad, ϕ=90^o

1mm Be pipe

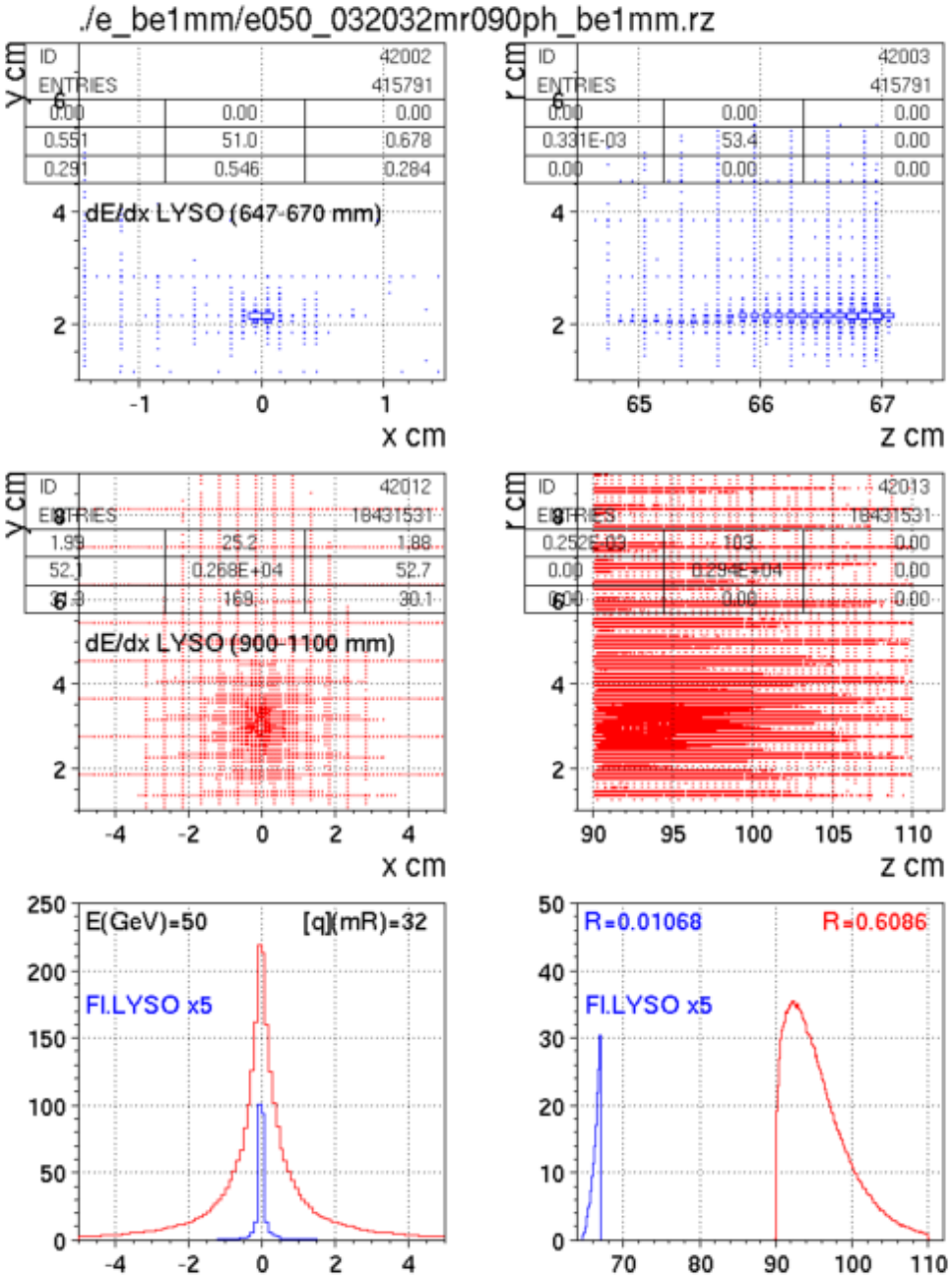
Shower deposition

in front LYSO: 1.0%

In back LYSO: 94%



Shower in LYSOs w. Flange+Bellow ($4X_o$)



50 GeV electron

θ = 32 mRad, ϕ=90°

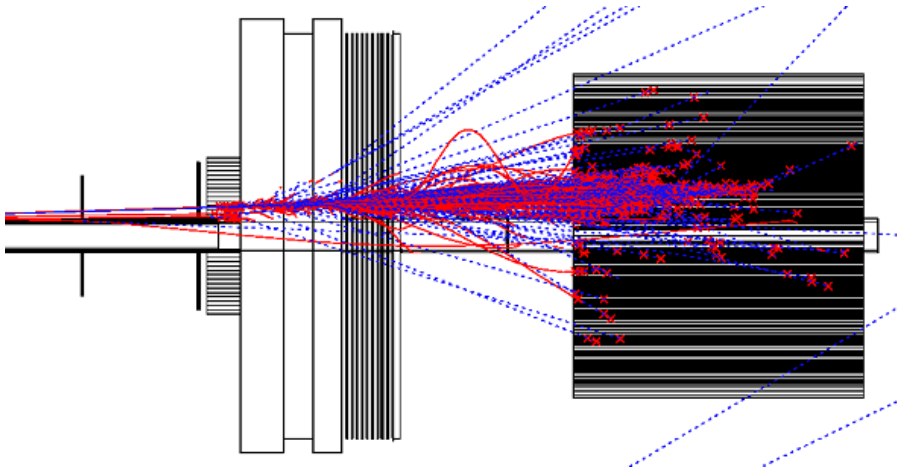
1mm Be pipe

Shower deposition

in front LYSO: 1.0%

In back LYSO: 61%

➔ 33% shower in flange+bellow



Summary

LumiCal for 10^{-4} systematics:

- Racetrack ø 20 mm, $|y|<20$mm, gives Bhabha cross-section twice of $Z \rightarrow qq$
- Survey precision of fiducial edge is the primary factor to systematics of 10^{-4}
- Multi. Scatt. and Shower smear Bhabah δN in figucial
- Smearing effects are symmetric error on mean $\rightarrow \delta N/N < 10^{-4}$
- Require redundency on electron tracking to detect smearing and offset of the figucial edge