Requirements on Luminometer Geometrical Precision

FCC-ee MDI Workshop
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Simulate luminosity events

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- Generate **2×10^8** radiative Bhabha events using Bhlumi event generator and write to file
  - Make sure events generously cover detector acceptance:
    - E_{cm} = 92.3 GeV (simply the value set by default in Bhlumi)
    - θ_{min} = 35 mrad
    - θ_{max} = 250 mrad
    - σ = 102 nb
    - Few hours CPU, 21 GByte

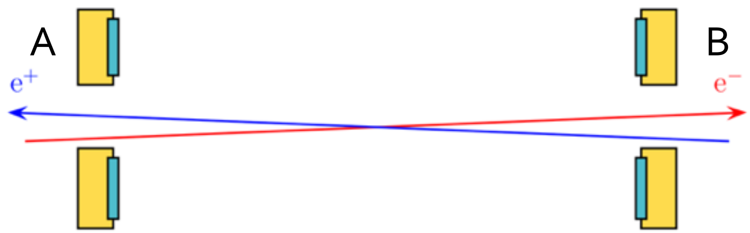
Narrow acceptance
- θ_{min} = 54.5 mrad
- θ_{max} = 109 mrad
- **σ = 30.2 nb**

We may rather have
- θ_{min} ~ 70 mrad
- θ_{max} ~ 80 mrad
- **σ ~ 6 nb**

Study to be updated

Update

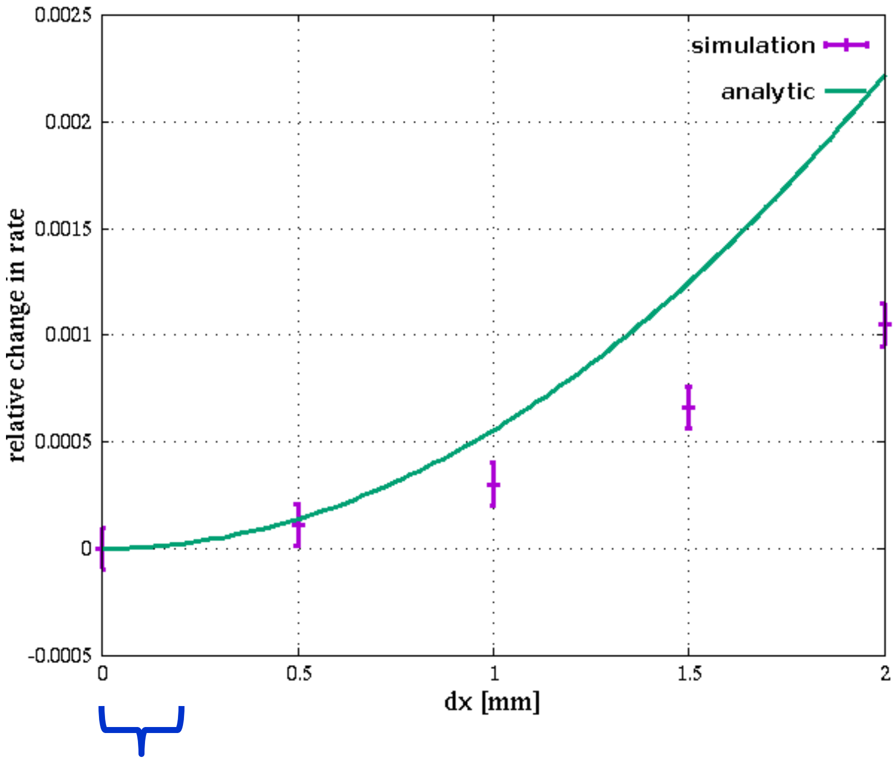
- Cluster events on each calorimeter surface
  1. Accept particles hitting calorimeter surface (50 mm < r < 130 mm)
     - First time around, no correction for lateral leakage
  2. Form clusters by merging secondary particles to primary particle if distance less than 10 mm
     - Cluster: energy = sum, position = barycenter
- Count "luminosity events" based on clusters in the two sides A and B (OPAL inspired cuts)
  - Energy of both clusters > 0.5 E_{beam}
  - $E_A + E_B > 1.5\, E_{beam}$
  - Two counting rates:
    - SideA: NarrowA + WideB
    - SideB: NarrowB + WideA
  - Total rate: Average of SideA and SideB



Variation of IP position - transverse

- Study based on BHLUMI event generator
- First study transverse displacement of IP wrt detector frame

How well are luminomiters centred around outgoing beam?



$$\frac{\delta \bar{R}}{\bar{R}} = 2\left(\frac{\delta x}{r_{\min}}\right)^2$$

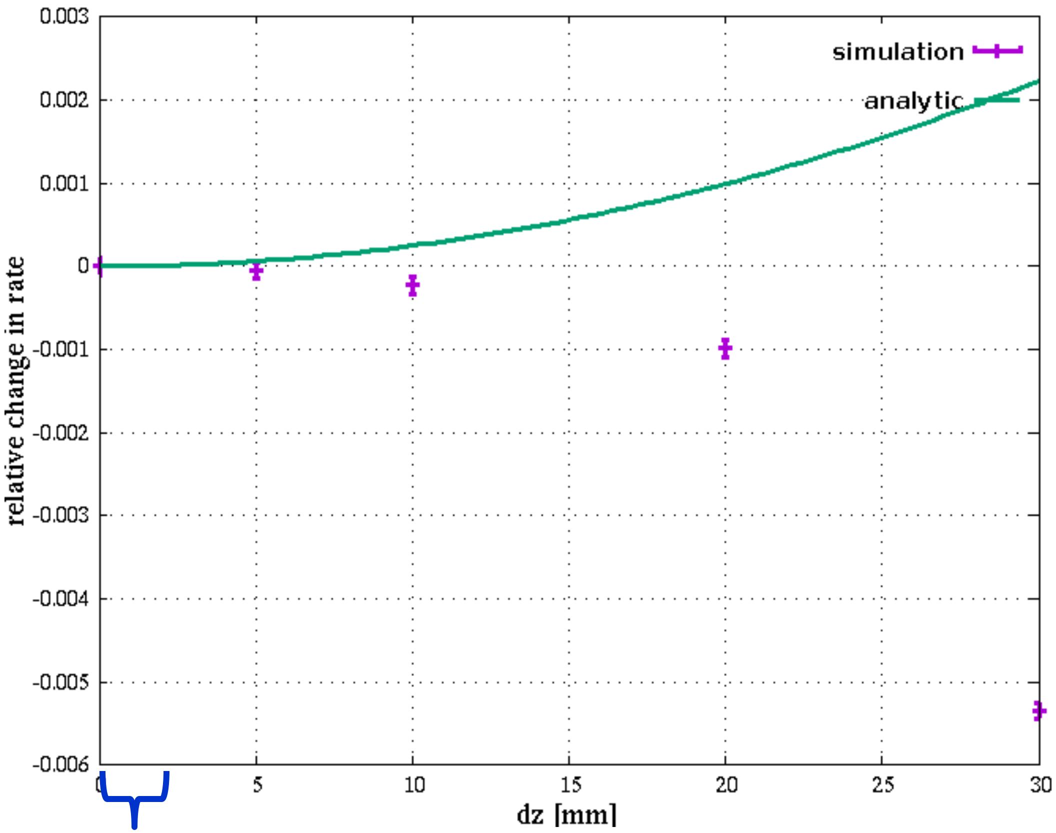
Stat precision ~10^{-4}

- Negligible correction, if δx ≲ 200 µm
- For higher values of δx, have to correction
- Keep δx as low as possible where slope is low

Variation of IP position - longitudinal

- Longitudinal displacement of IP wrt detector frame

How well is the set of two luminomiters centred in z direction w.r.t. IP position?

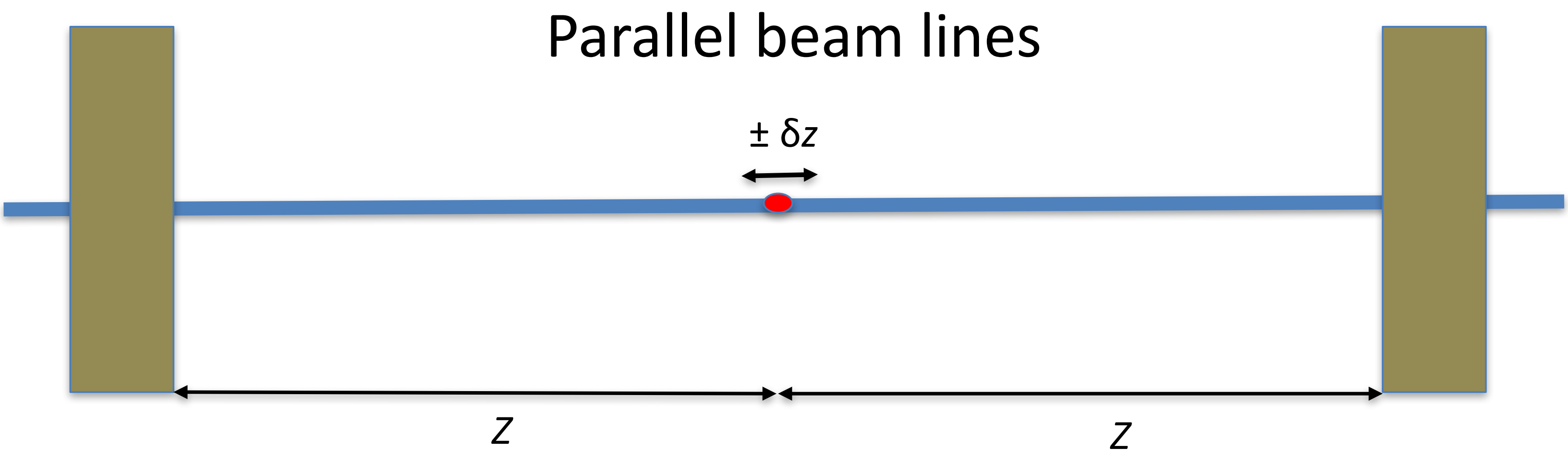


$$\frac{\delta \bar{R}}{\bar{R}} = 3 \left(\frac{\delta z}{Z} \right)^2$$

Stat precision ~10^{-4}

- Negligible correction, if $\delta z \lesssim 2$ mm
- For higher values of δz, have to apply correction
- Keep δz as low as possible where slope is low

FCC-ee Specifics: Crossing angle (i)



Change in acceptance

- From IP z position

$$\frac{\delta A}{A} = 3\left(\frac{\delta z}{Z}\right)^2$$

  – $O(3 \times 10^{-6})$ for $\delta z = 1$ mm

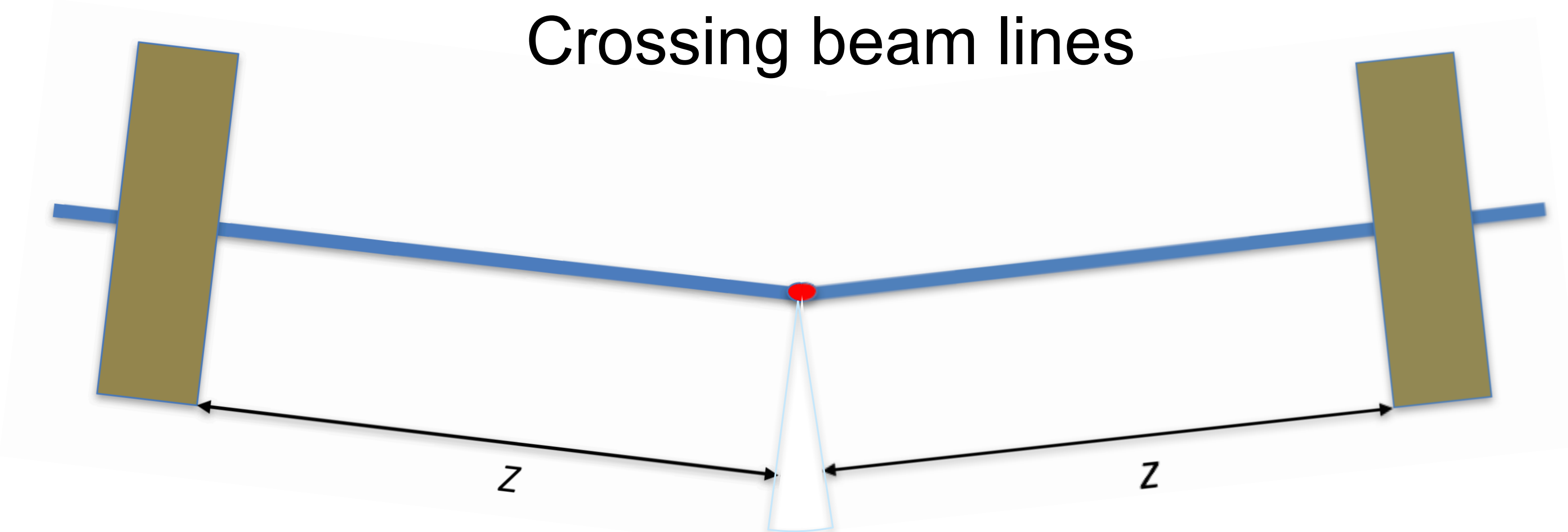
- From distance between two luminomiters

$$\frac{\delta A}{A} = 2\frac{\delta(2Z)}{(2Z)}$$

  – 10^{-4} for $\delta(2Z) = 100$ µm

Hence, should know the distance between the two luminomiters (2*Z*) to 100 µm

FCC-ee Specifics: Crossing angle (ii)



Change in acceptance

- From IP z position

was $\frac{\delta A}{A} = 3\left(\frac{\delta z}{Z}\right)^2$

  - Assume this effect is still small, of the order 10^{-6}. IP position cannot move "far" in z, if beams are to cross...?
- "Distance between two luminomiters"
  - Situation changed – now we have two luminomiters the faces of which should be perpendicular to beam line, i.e. the faces are not parallel to each other.
  - Need to measure the two Z distances separately each to 50 µm
    - Measure w.r.t. what? Fiducial mark...?

OPAL Experience

"… the measurement is based on interferometric and Johansson bar measurements of the distance between flanges on the ***OPAL beam pipe and pressure pipes****. These pipes* ***are then used as rulers to measure the distance between the calorimeters during operation****. … Optical grating position monitors with 0.5 μm resolution are used to measure the position of the calorimeters with respect to these pipes during detector operation. These monitors must track the relative motion of the calorimeters as the expansion of the central detector pressure vessel during its pressurizations to 4 bar carries them away from each ther by about 10 mm. …* ***Corrections at the nominal detector half-separation … are made with a precision of approximately 60 μm*** *…"*

Table 7. Summary of errors in correcting the nominal 246.0225 cm half-distance between the layer 7 reference planes of the two calorimeters

Systematic sources	1993–4	1995
Position of layer 7 relative to calorimeter reference face	34 μm	60 μm
Length of the pressure and beam pipes	31 μm	31 μm
Position monitor stability	5 μm	2 μm
Reference pipe temperature during calibration	10 μm	0 μm
Reference pipe temperature during operation	15 μm	4 μm
Total axial metrology systematic error	50 μm	68 μm
Corresponding error in acceptance	0.41×10^{-4}	0.55×10^{-4}

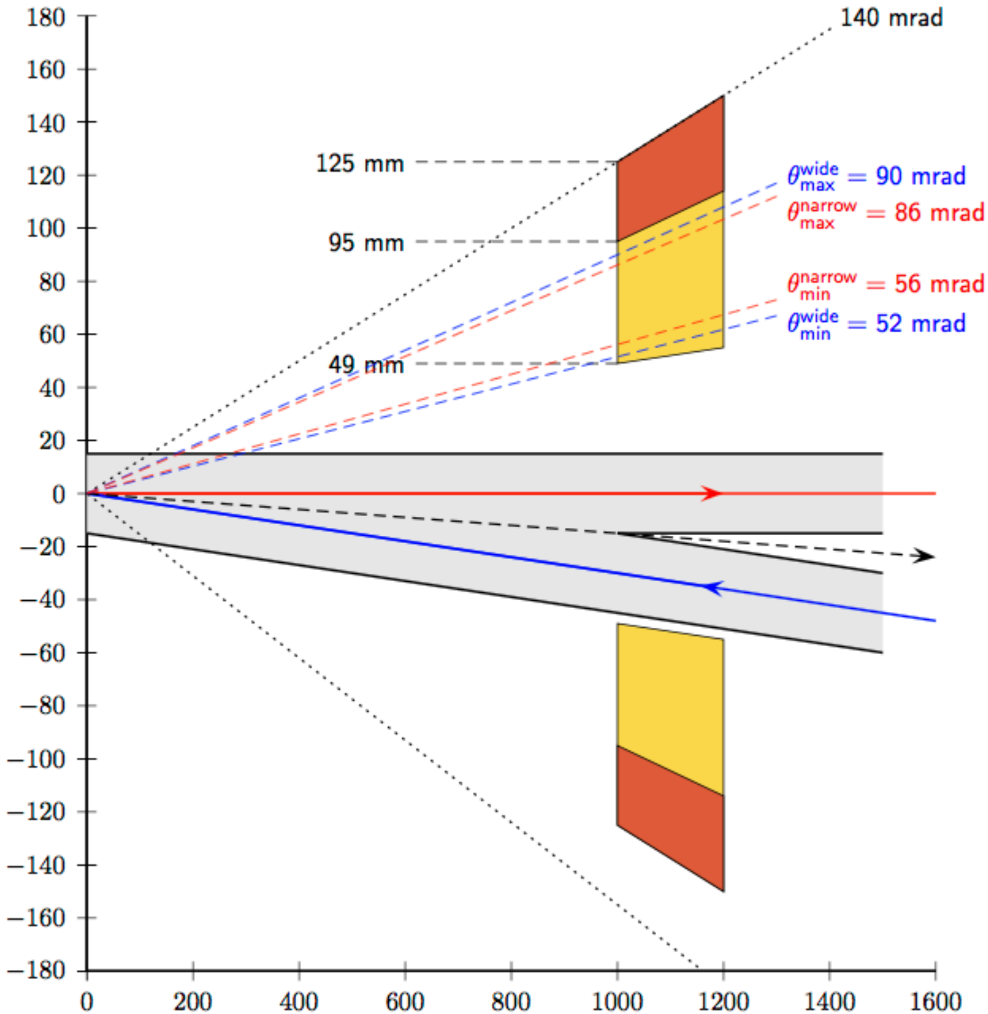
LumiCal internal geometry actually the largest effect

Richard Kellogg, *Lessons of the OPAL Lumi Measurement*, 2002:
"Remember to measure your beam pipe before installation!"

Extra slides
Luminometer geometry

Updated thoughts on luminomiter geometry

Berlin geometry



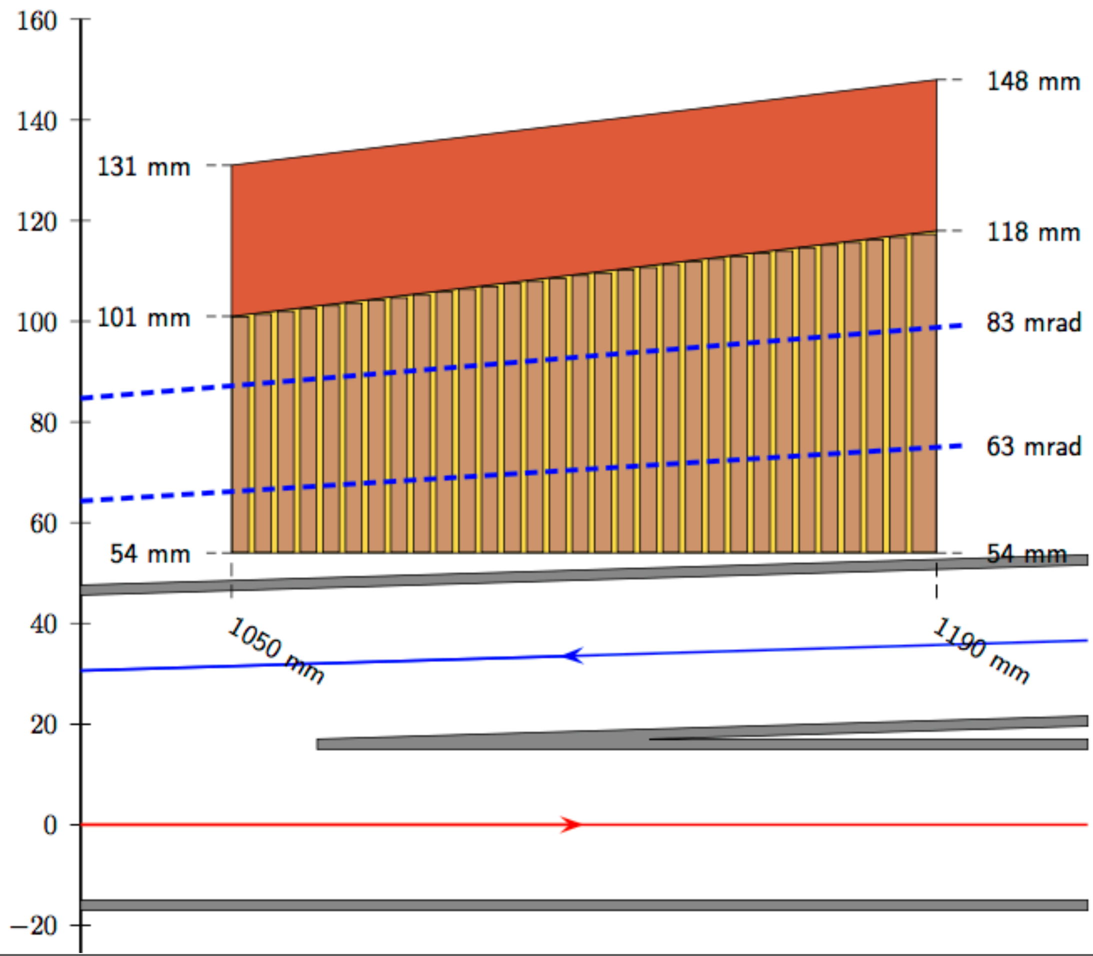
I was too optimistic here, I now believe: Probably have to keep acceptance at least one Moliere radius away from border of detector

Wide: 52-90 mrad → 58-80 mrad
Narrow: 56-86 mrad → 63-75 mrad
Cross section: 23 nb → 10 nb

Geometry thoughts (ii)

I do not believe in conical geometry (i):
- Have to keep geometrical precison to 1 μm at inner border

Inner border: cylindrical
Outer border: conical



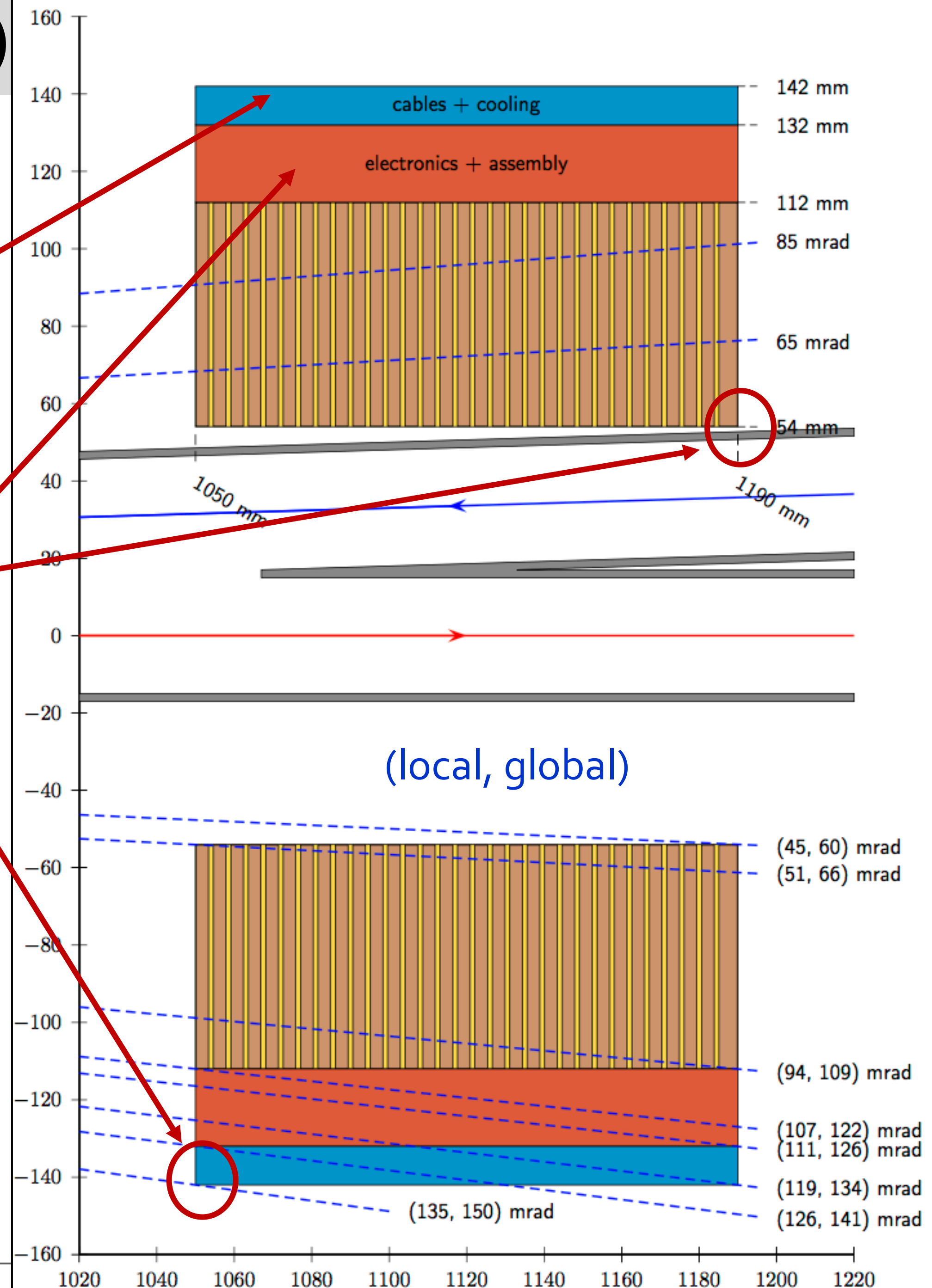
Hmmmm….
Still not happy

Geometry thoughts (iii)

I do not believe in conical geometry (ii):

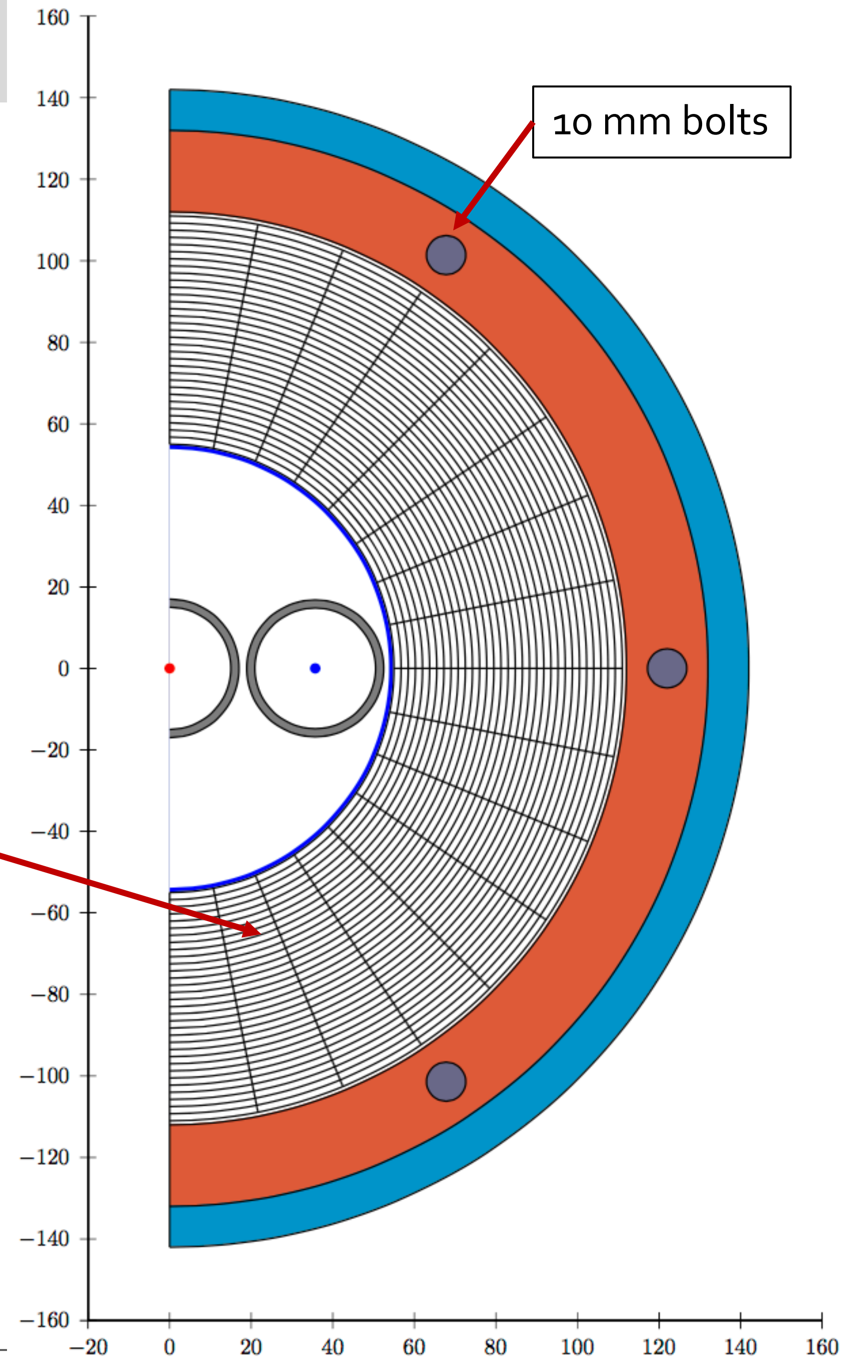
- Have to keep geometrical precison to 1 µm at inner border

- Mostly light materials
- Light materials except mechanical assembly at 6 (say) points in azimuth
- Corner 18 mm from beam, can go closer?
- Touches 150 mrad in global coordinate system for one azimuth

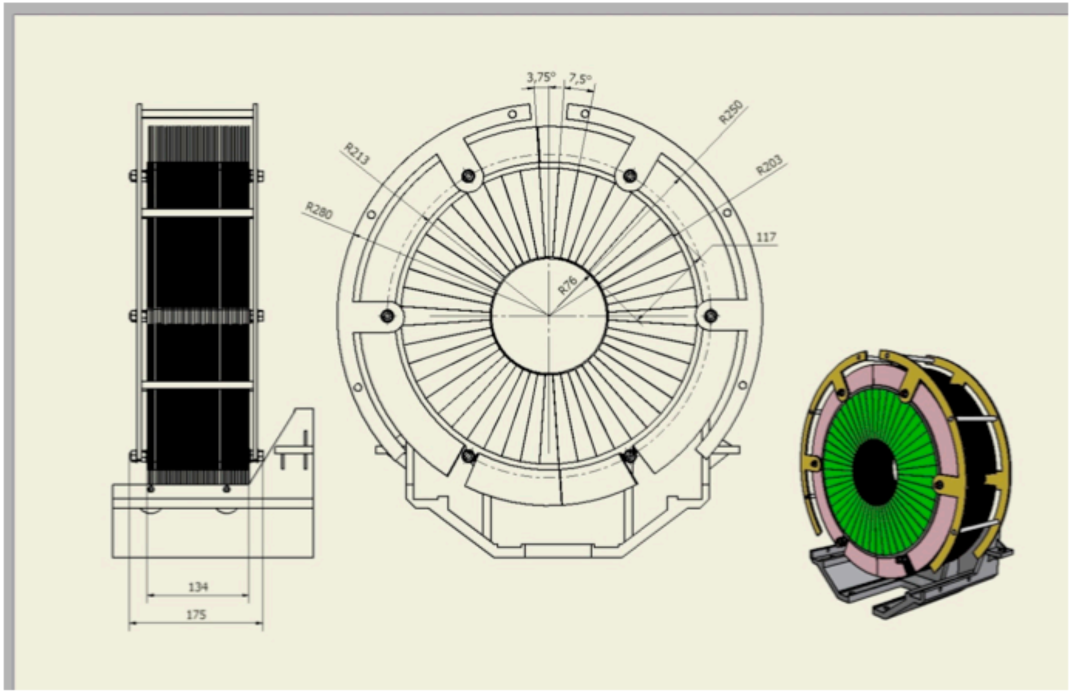


Geometry thoughts (iv)

- 30 layers of 1 X_0 each
  - 3.5 mm W + 1.0 mm (320 µm Si, kapton, cables)
  - Total of 140 mm for 30 X_0
    - probably could do with 25 X_0 (115 mm)
- All layers have same segmentation
  - 32 r-pads of 1.75 mm
  - 32 ϕ-pads of 11.25°
  - Total of 1024 channels per layer
  - 20280 channels per luminomiter
    - 100 W for 5 mW per channel
  - Si pads made from one single 10 inch wafer ?
    - No borders; no energy loss



Geometry thoughts (v)



Same geometry as in ILC work , but smaller

EUDET-Memo-2010-06

I believe the cylindrical geometry **can actually be build to a very good precision.**

Advantages

- All Si layers identical
- Only one (or perhaps two) different W-layer geometries
- For metrology, all layers identical

Disadvantages

- Somewhat lower cross section, can reach ~6 nb
- Extends to 150 mrad at the outermost point

128 channels