LumiCal Design

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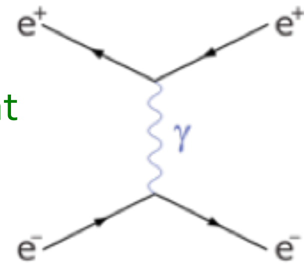
Luminosity Monitoring with Bhabha scattering

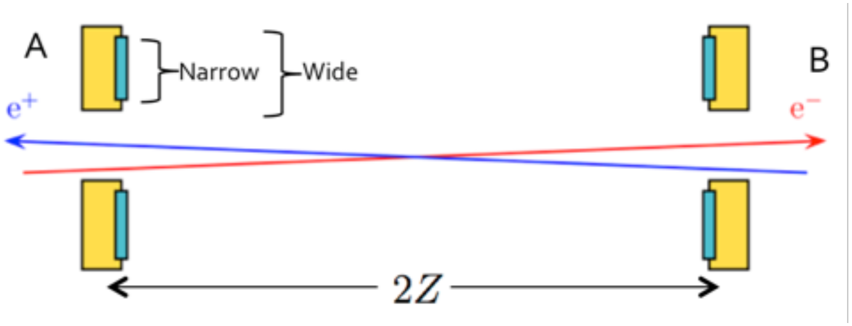
Luminosity monitoring:

- **Absolute** – target precision $\mathbf{10^{-4}}$
  - May be best achieved through the process $e^+e^- \rightarrow \gamma\gamma$ (?)
- **Relative** for Z lineshape measurement – need a relative precision of $\mathbf{5 \times 10^{-5}}$
  - Need cross section comparable to Z production:, i.e. ≥ 15 nb
  - Can be achieved via **small angle Bhabha scattering $e^+e^- \rightarrow e^+e^-$**
    - Very strongly forward peaked – control of angular acceptance very important



$$\sigma^{\text{Bhabha}} = \frac{1040 \text{ nb GeV}^2}{s}\left(\frac{1}{\theta_{\text{min}}^2} - \frac{1}{\theta_{\text{max}}^2}\right)$$

- Measured with set of two calorimeters; one at each side of the IP

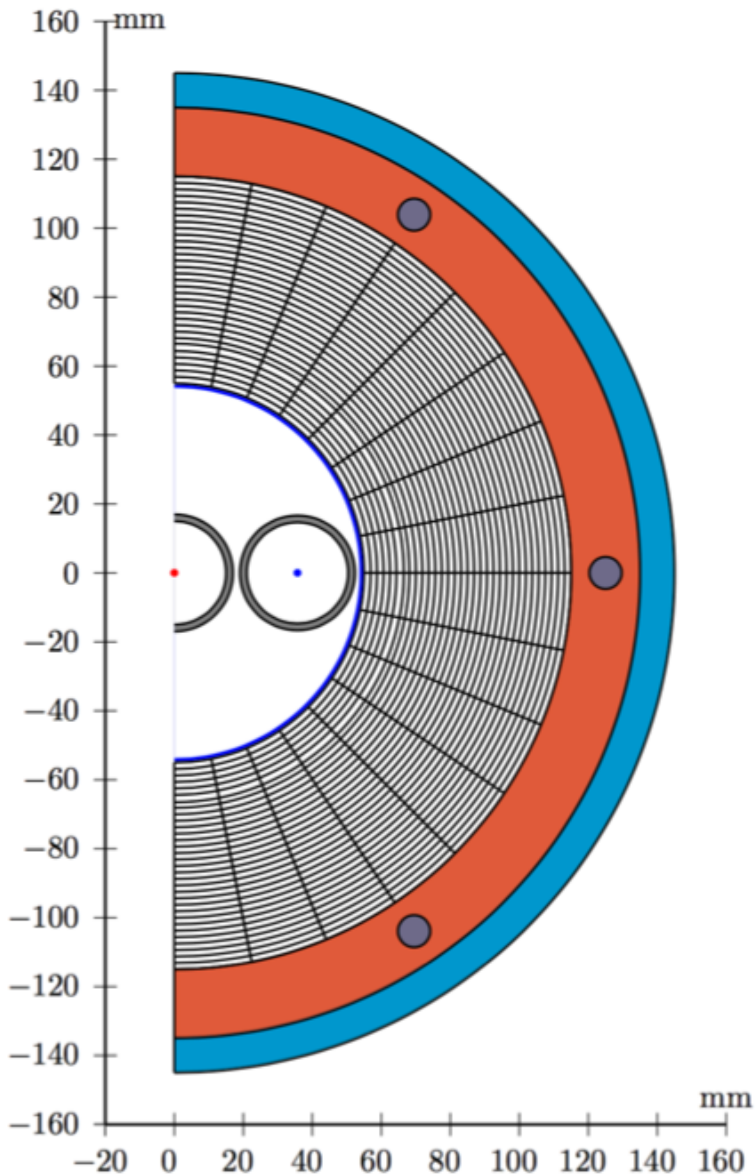


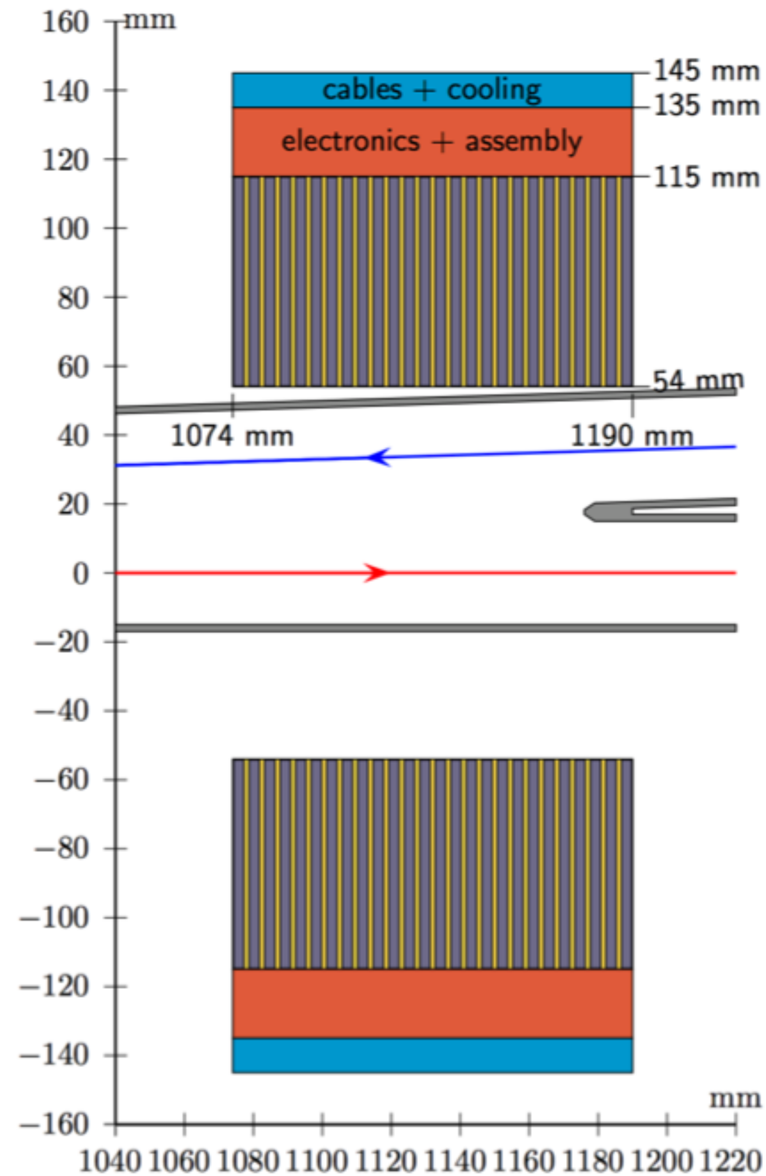
Two counting rates:
- SideA = NarrowA + WideB
- SideB = NarrowB + WideA

- Average over SideA and SideB rates: Only dependent to second order on beam paramaters:

$$\frac{\delta \bar{R}}{\bar{R}} = 3\left(\frac{\delta z}{Z}\right)^2 \qquad \frac{\delta \bar{R}}{\bar{R}} = 2\left(\frac{\delta x}{r_{\text{min}}}\right)^2$$

LumiCal Design





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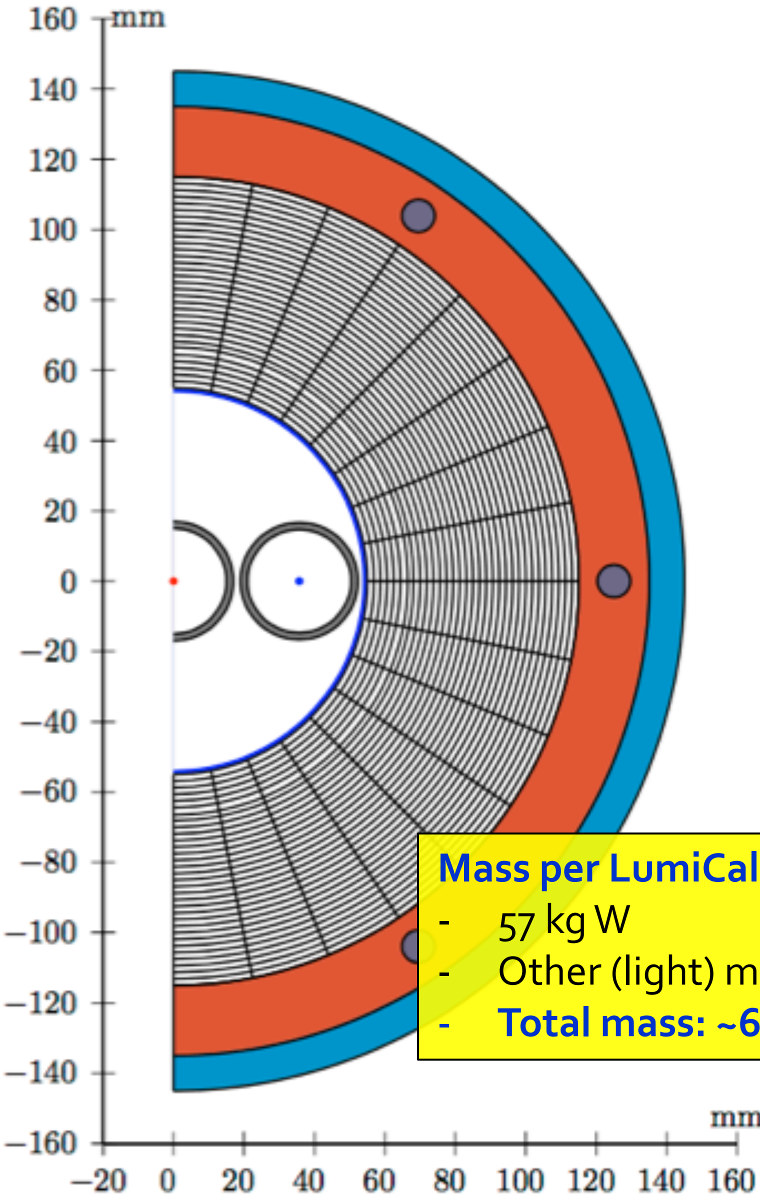
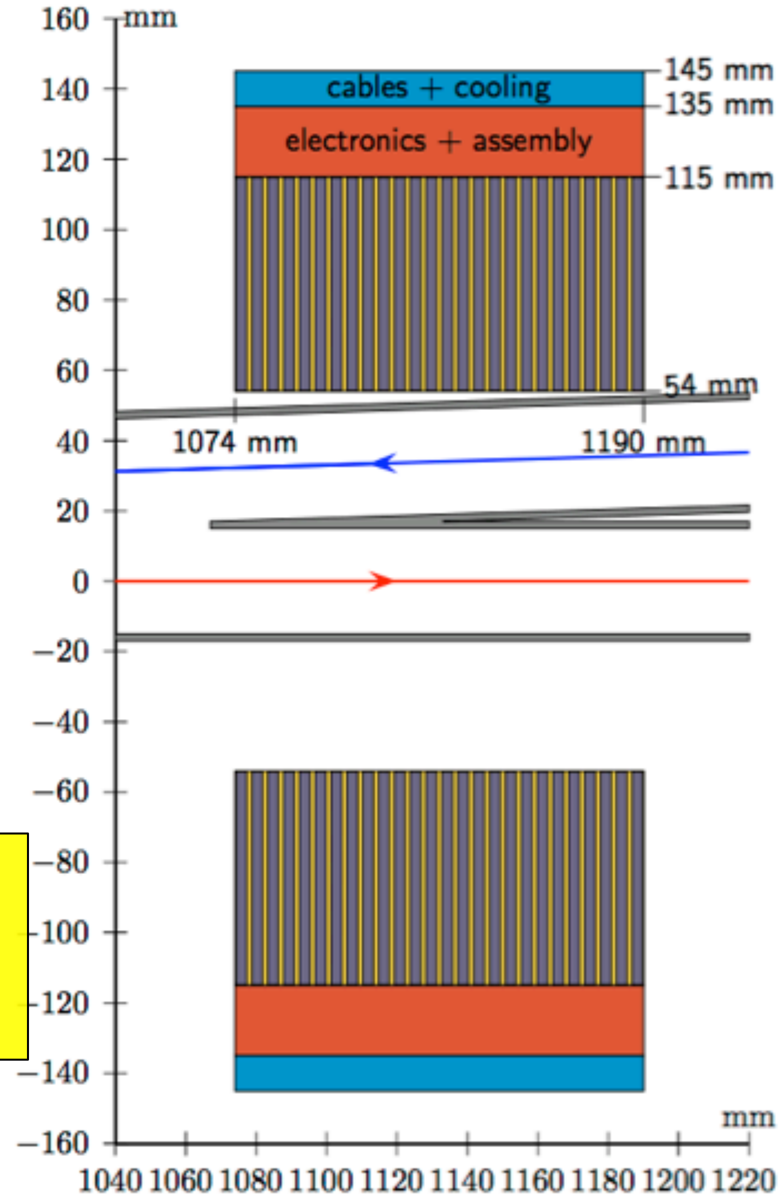
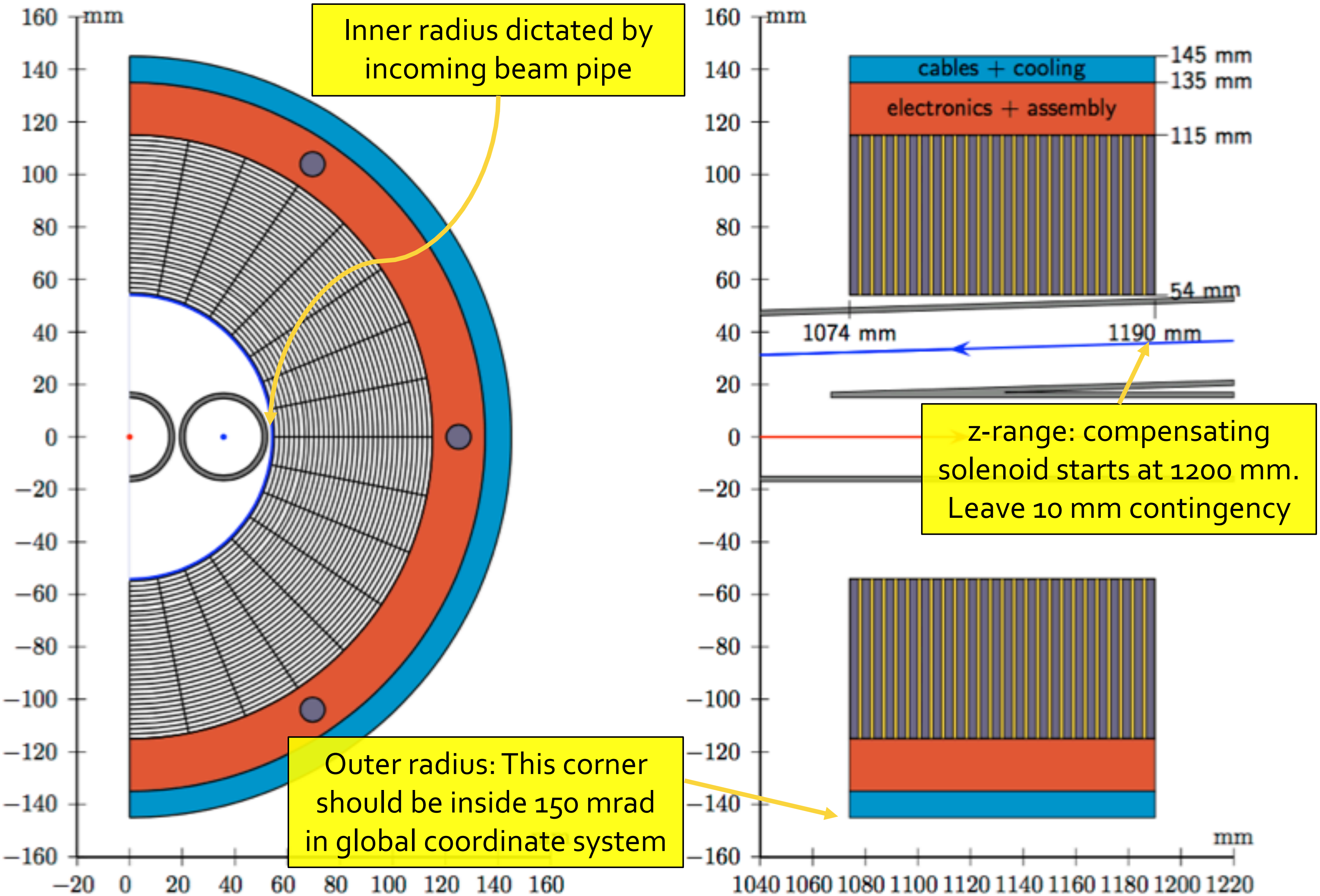




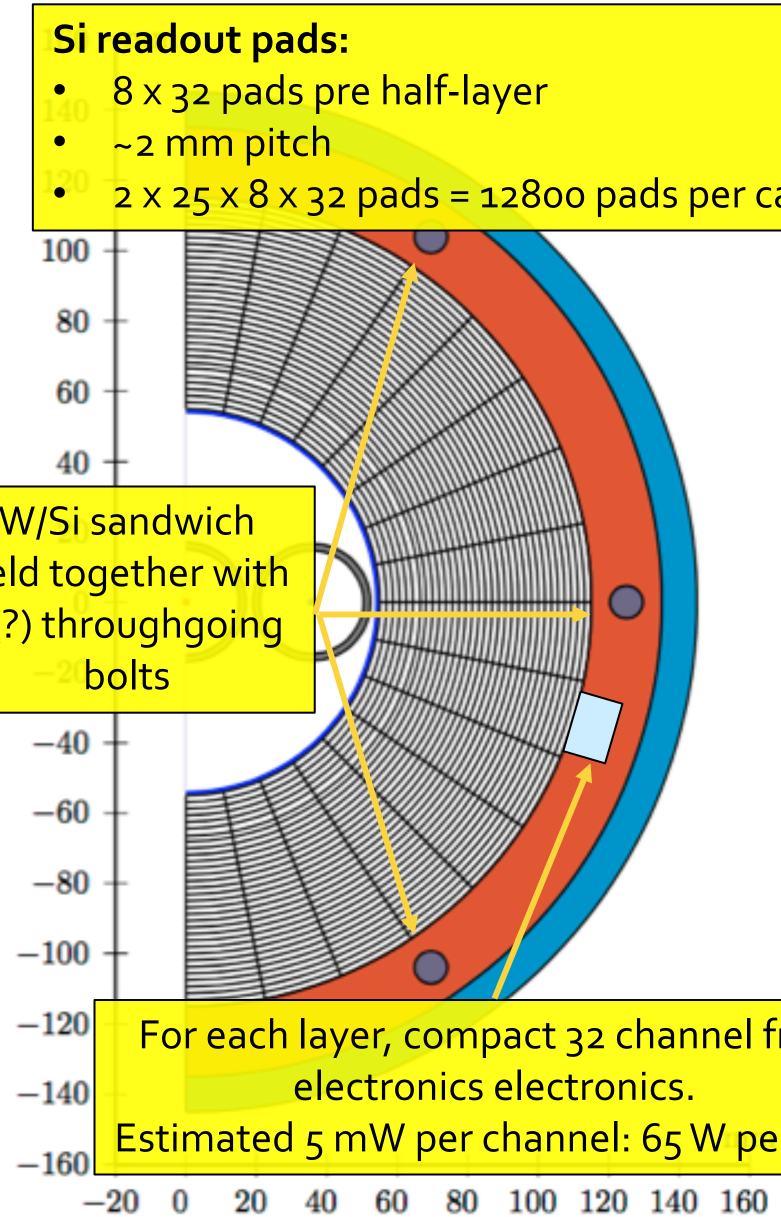
Mass per LumiCal:
- 57 kg W
- Other (light) materials
- **Total mass: ~65 kg**

Geometrical Constraints



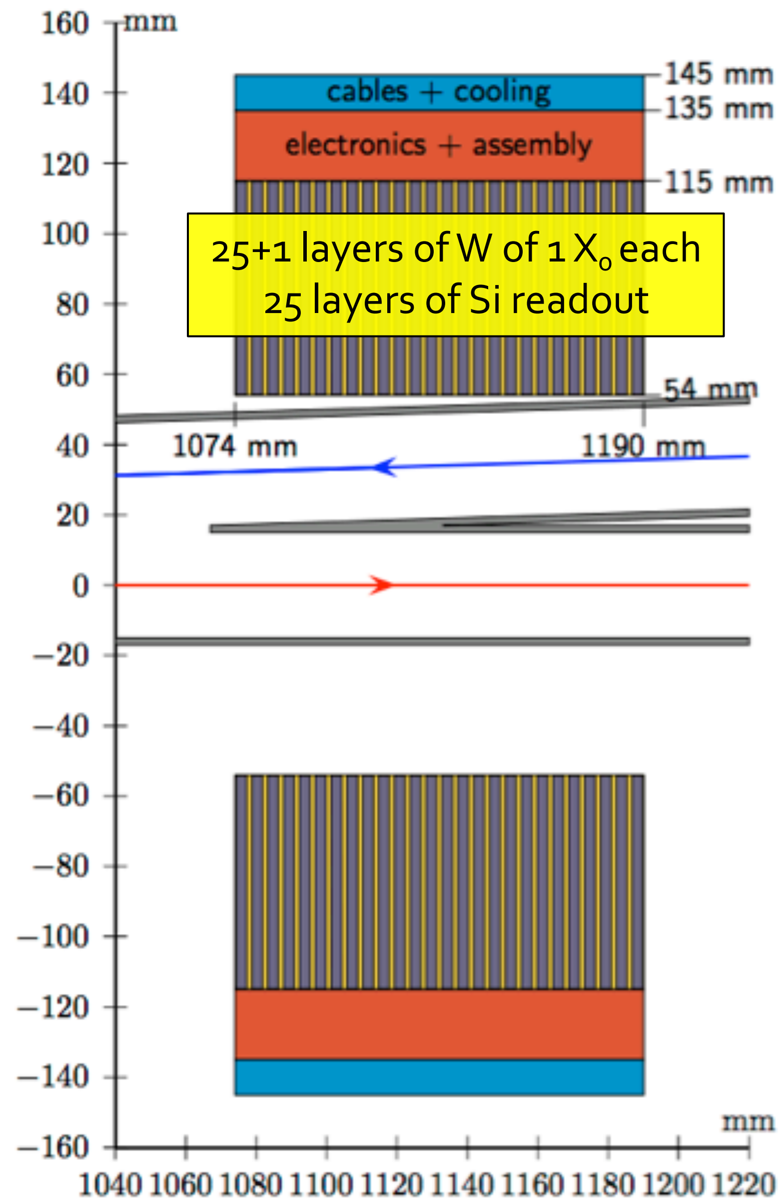
Design Details

Si readout pads:
- 8 x 32 pads pre half-layer
- ~2 mm pitch
- 2 x 25 x 8 x 32 pads = 12800 pads per calo



W/Si sandwich held together with 3(?) throughgoing bolts

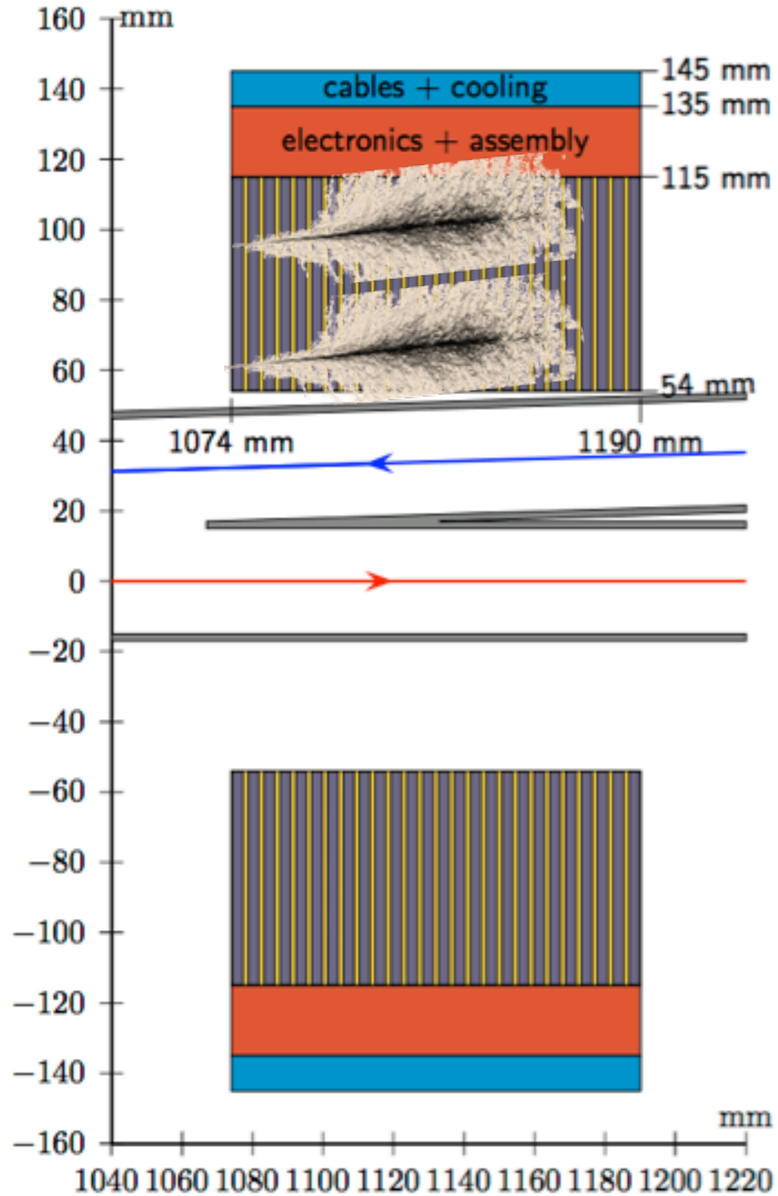
For each layer, compact 32 channel front electronics electronics.
Estimated 5 mW per channel: 65 W per calo



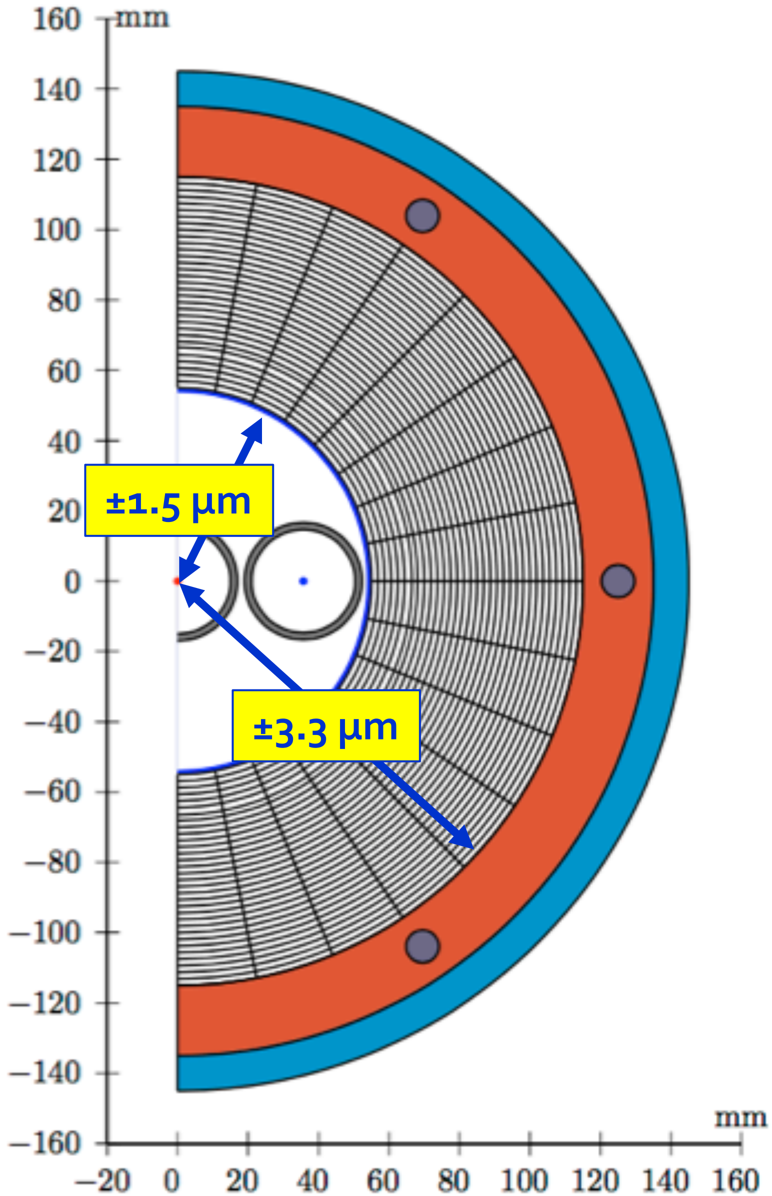
25+1 layers of W of 1 X_0 each
25 layers of Si readout

Acceptance and tolerances

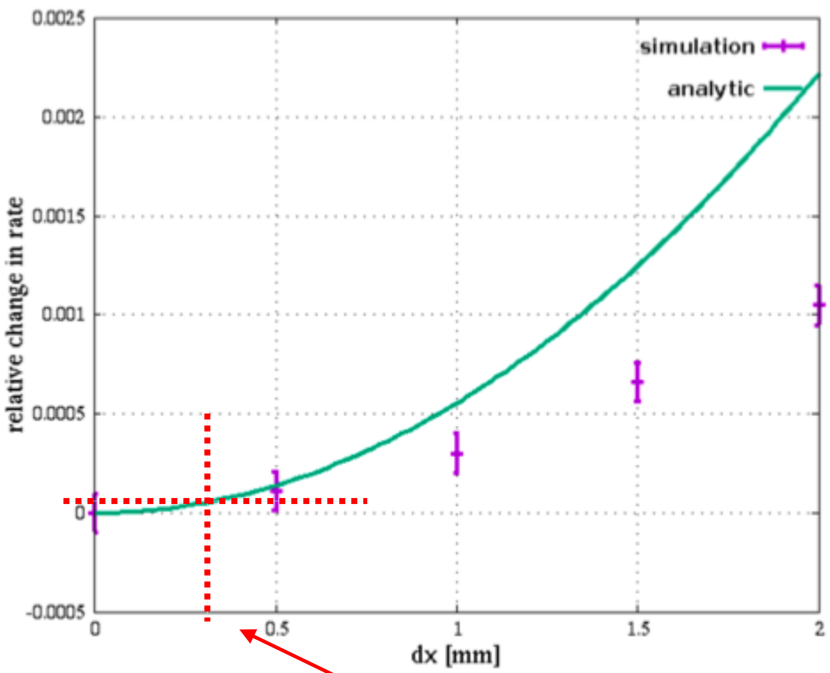
- Effective Moliere radius of W-Si sandwich: **~15 mm**
- Stay 1 Moliere radius away from both inner radius and somewhat more at outer radius
  - To be optimised
- => **Wide acceptance: 63 – 88 mrad**
- Slightly smaller **narrow acceptance**: **65 – 85 mrad**
  - **Bhabha cross section: 12 nb**
    - Compare to 30 nb multihadronic Z decays at peak
- Geometrical tolerances for shift in acceptance of 10^{-4}:
  - **Inner border: $\delta\Theta_{min}$ = ± 1.3 μrad ; δR_{min} = ± 1.5 μm**
  - **Outer border: $\delta\Theta_{max}$ = ± 3.0 μrad ; δR_{max} = ± 3.3 μm**
  - **Half distance between two calorimeters: δZ = ± 55 μm**



Geometric Tolerances - Radial



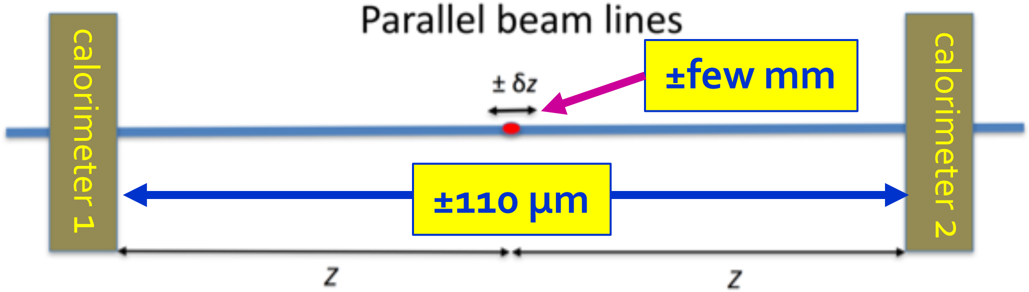
Centering of calorimeters around beam line



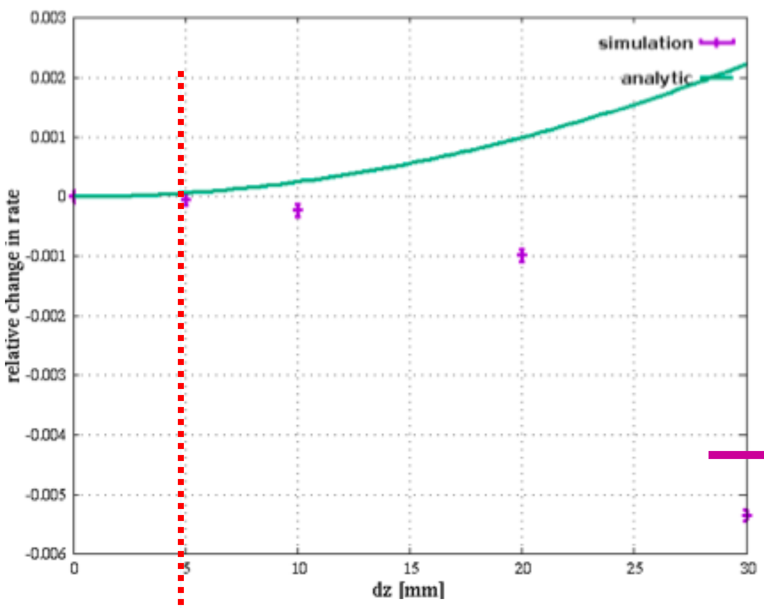
Transverse shifts should be δr < 300 μm

Geometric Tolerances – Longitidinal (i)

First, let us consider example of parallel beams



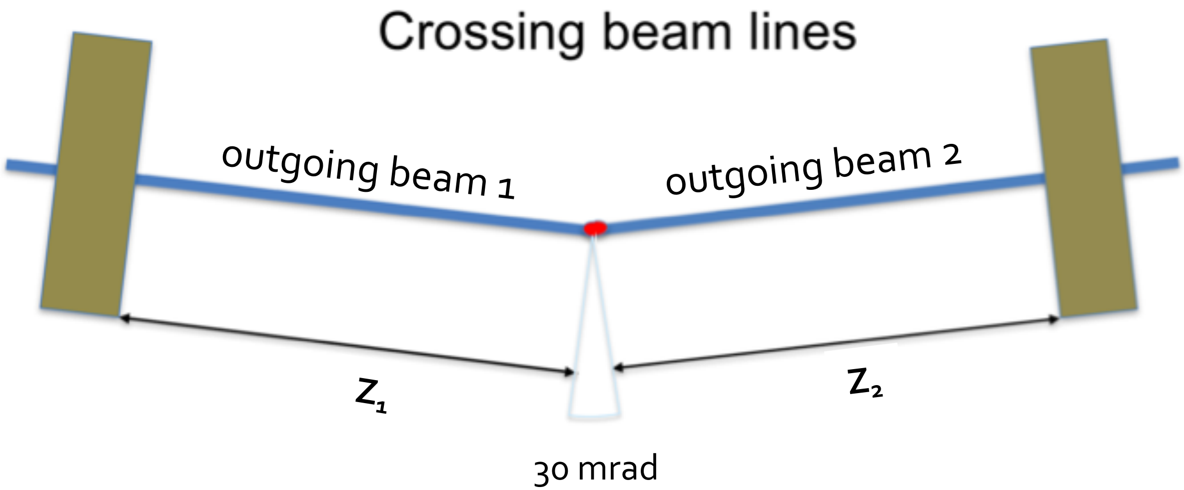
Centering of IP w.r.t. two-calorimeter system



- **Distance between two calorimeters should be known to**
  2 x δZ = 2 x 55 μm = 110 μm
- **IP position in two-calorimeter system can be off by few mm**

Longitudinal shifts of IP position up to few mm are tolerable

Geometric Tolerances – Longitidinal (ii)



- Now, have two distances, Z_1 and Z_2, to measure each to **±55 µm**
  - To be measured **w.r.t.** fiducual marker indicating **nominal IP position**
- Drift of the IP of the order of few mm in the "longitudinal" direction still tolerable
  - Of course, now, longitudinal and transverse coordinates are coupled

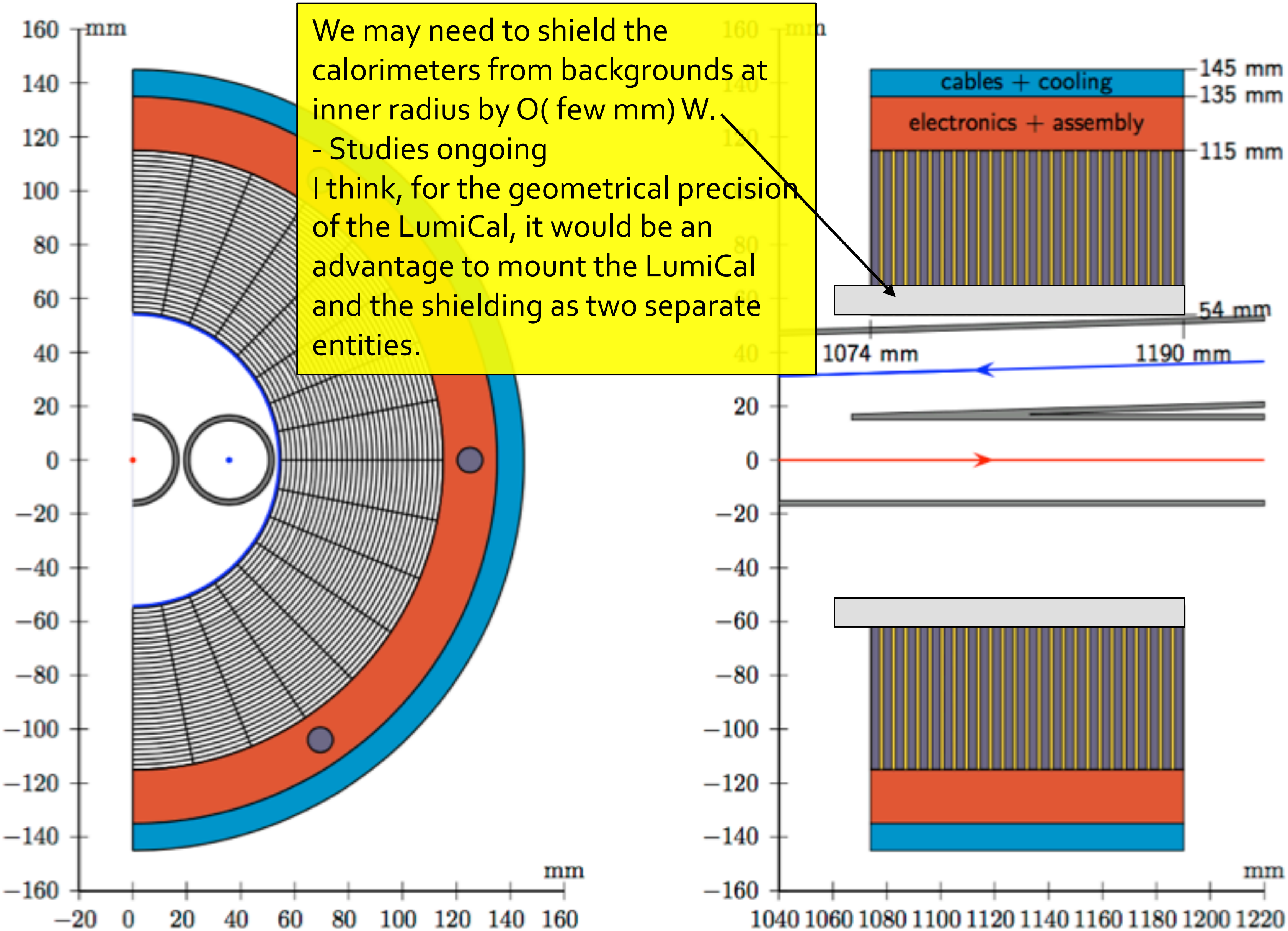
Notice:

- As indicated, the face of each LumiCals shall be perpendicular to the corresponding outgoing beam line.
- The two faces will not be parallel, they ar eeach tilted by 15 mrad w.r.t. the global coordinate system.

Shielding towards beam pipe?

We may need to shield the calorimeters from backgrounds at inner radius by O(few mm) W.
- Studies ongoing

I think, for the geometrical precision of the LumiCal, it would be an advantage to mount the LumiCal and the shielding as two separate entities.



Summary of geometrical tolerances

- Geometrical tolerance on (system of two) LumiCals:
  - Inner radius: $\delta R_{min} = \pm 1.5$ µm
  - Outer radius: $\delta R_{min} = \pm 3.3$ µm
  - Longitudinal distance between each LumiCal and nominal IP: $\delta Z = \pm 55$ µm

- Geometrical tolerance of IP position w.r.t. LumiCal system:
  - Transverse: ± 300 µm
  - Longitudinal: ± few mm

Mechanical Issues

- Internal to LumiCal
  - Assembly and meterology/alignment of Si readout pads to ~1.5 μm radial precision
  - Need cooling to remove ~100 W of heat per calorimeter
    - Stability to ±1 C° for geometrical precision
    - Cold and/or warm neighbours?
  - May need (thin – few mm) shielding towards beam pipe.
    - Supported from LumiCal or from beam pipe?

- External to LumiCal
  - How and from what is LumiCal supported?
    - Need very high precision: distance LumiCal/nominal IP to be controlled/measured to ~50 μm level
      - By how much will compensating magnets move when powered up?
  - And of course: Please no material in front of acceptance except (thin) beam pipe!