Dual-Readout Calo 4π Geometry with Tubes in DD4hep

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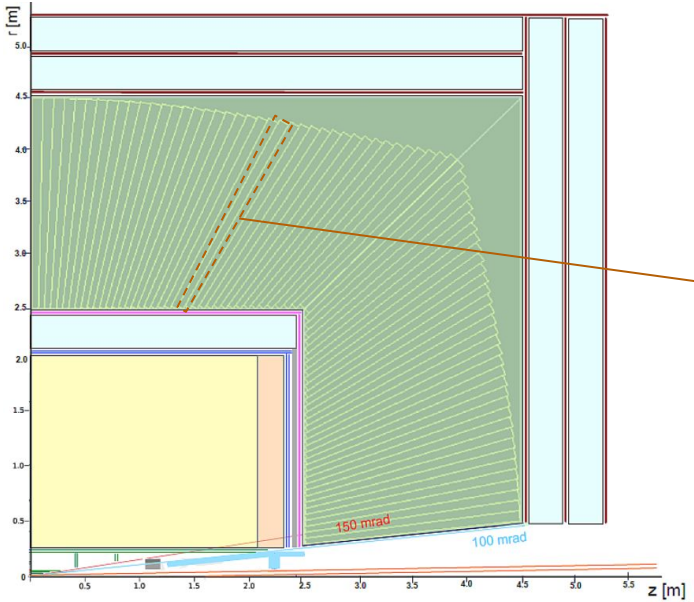
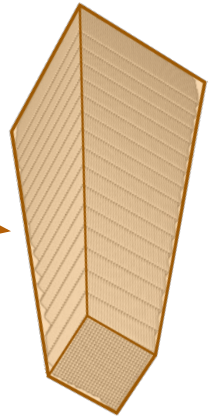
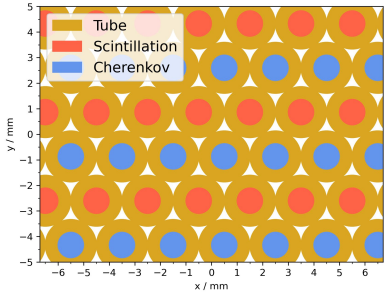
IDEA Fibre Dual-Readout Calorimeter [resource]



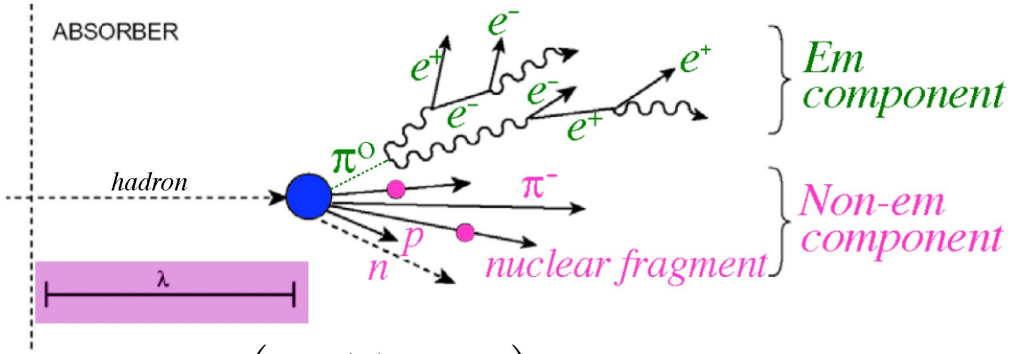




- Calorimeter build from **projective towers**
- **Copper/brass/steel** capillary tubes as absorber
- Fibres embedded in tubes in longitudinal direction:
  - 0.5 mm radius fibres, 1 mm radius tubes
  - Hexagonal layout of **Cherenkov** and **Scintillation** fibres
  - Readout in the rear end by SiPMs
- High transverse granularity:
  - Excellent angular resolution
  - Lateral shower shape sensitivity
- No longitudinal segmentation (out of the box)
- Calorimeter depth of 2 m (~8 λint)

Dual-Readout Calorimetry [resource]

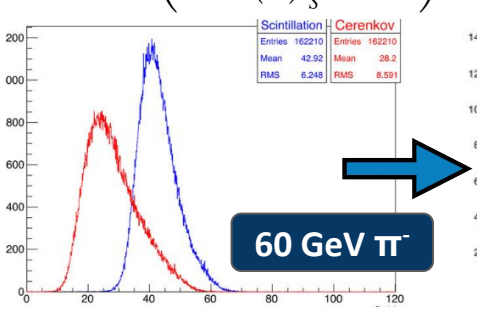
- Large fluctuations in fraction of **EM component** (f_{EM}) for hadronic showers
- If calorimeter response to **EM part** different from that to **non-EM part** (h/e ≠1): Energy resolution of calorimeter **largely limited by** f_{EM}
- Dual-Readout calorimetry allows to correct for fluctuations by **measuring** f_{EM} **event-by-event** using **two readout channels with different h/e**
  - **Scintillation** and **Cherenkov** channel
- Combining information from two readout channels **boosts energy resolution**

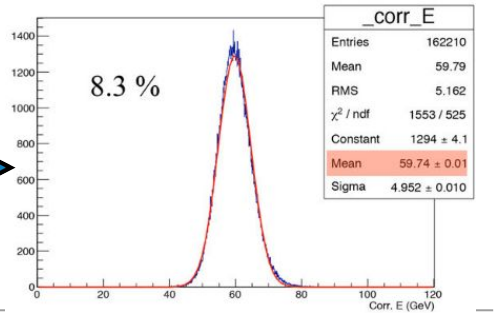


$$E_C = E\left(f_{em} + \left(\frac{h}{e}\right)_C (1 - f_{em})\right)$$

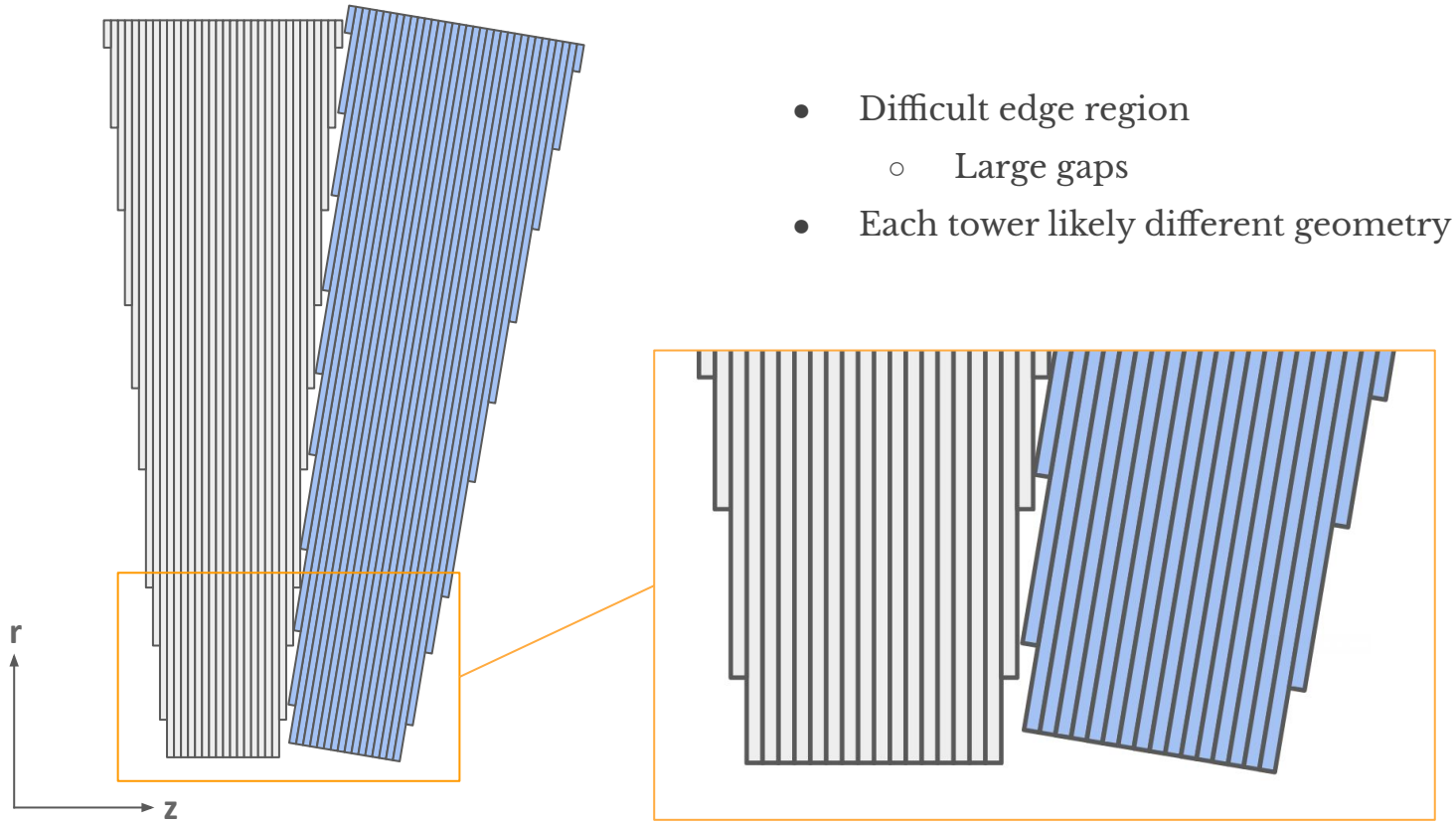
$$E_S = E\left(f_{em} + \left(\frac{h}{e}\right)_S (1 - f_{em})\right)$$

$$E = \frac{(E_S - \chi E_C)}{1 - \chi}$$





How to build projective towers with tubes?



- Difficult edge region
  - Large gaps
- Each tower likely different geometry

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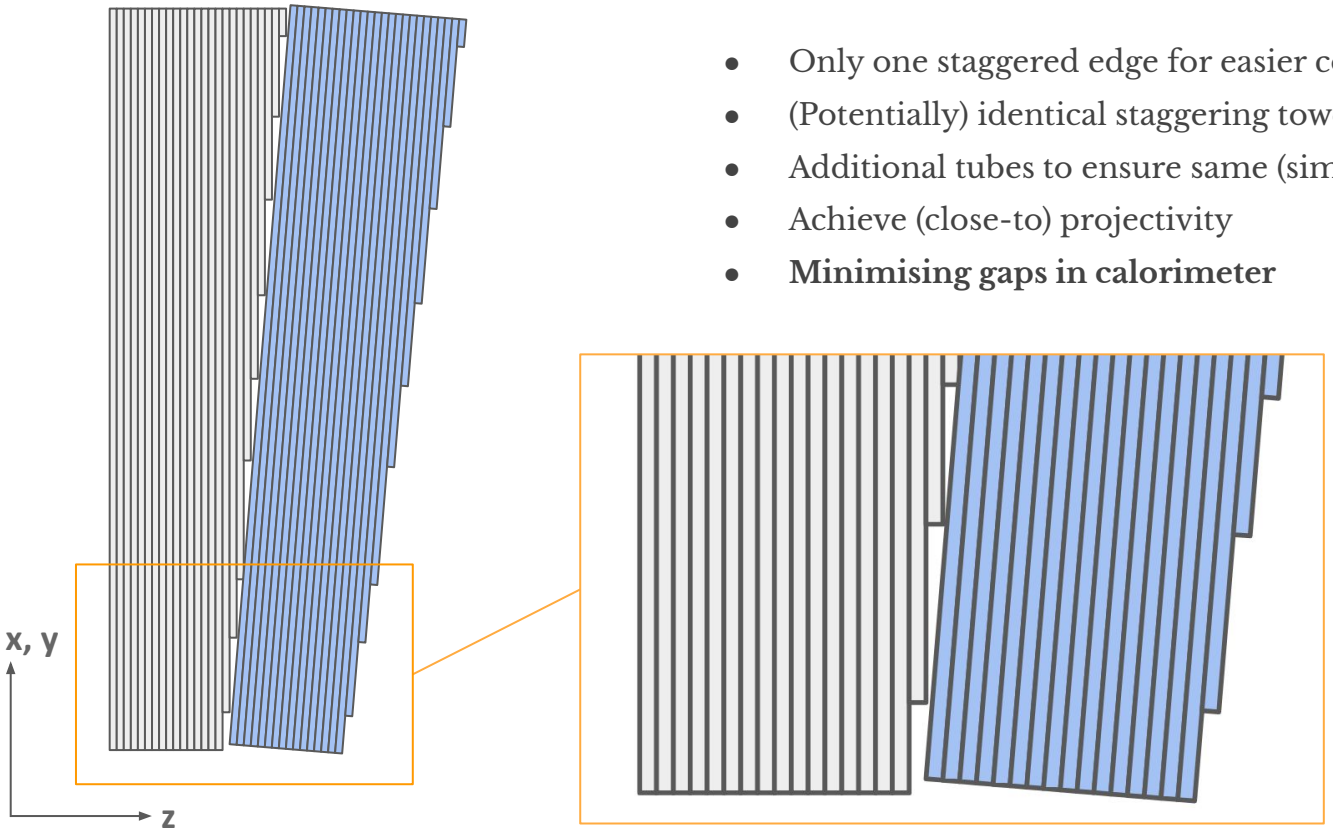
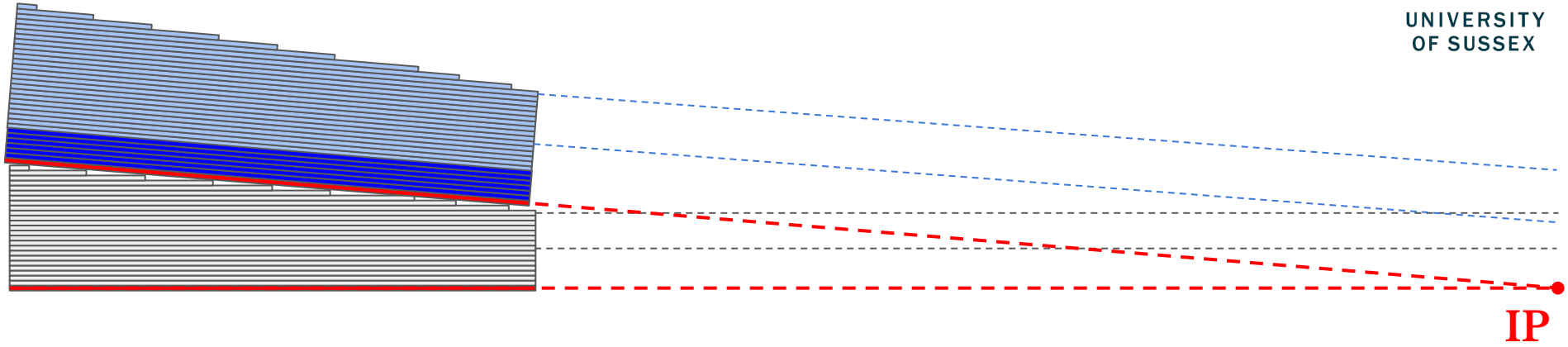
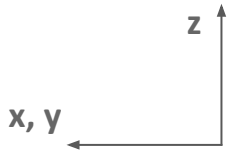


- Only one staggered edge for easier construction
- (Potentially) identical staggering towers
- Additional tubes to ensure same (similar) θ coverage
- Achieve (close-to) projectivity
- **Minimising gaps in calorimeter**

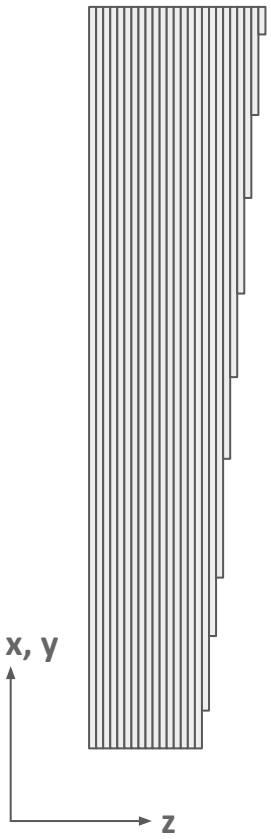
Projectivity





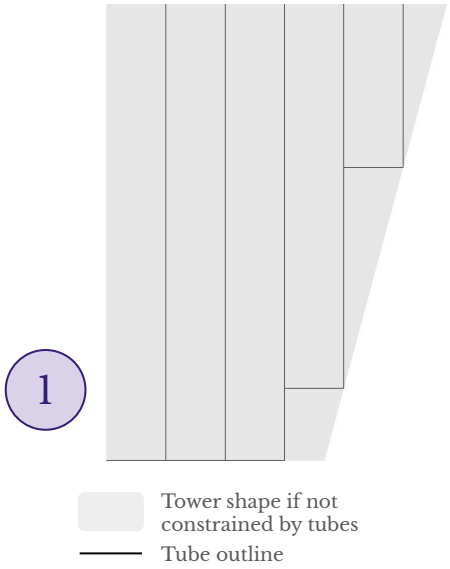
- Only “innermost” fibre is projective
- Other fibre’s projectivity decreases over the height of the tower

Constructing a Tower



Number of tubes:

- Front face not fitting whole number of tubes
- Keep tower size and θ fixed
- Definitely every tower different staggering



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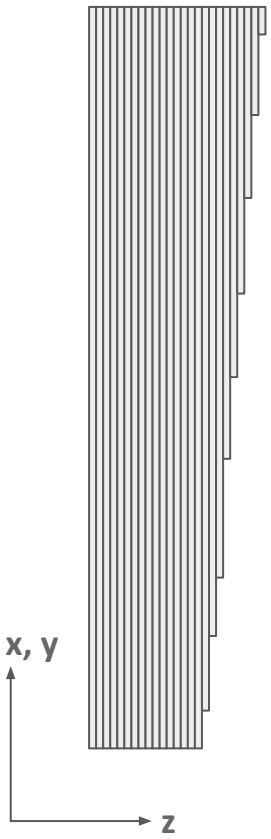

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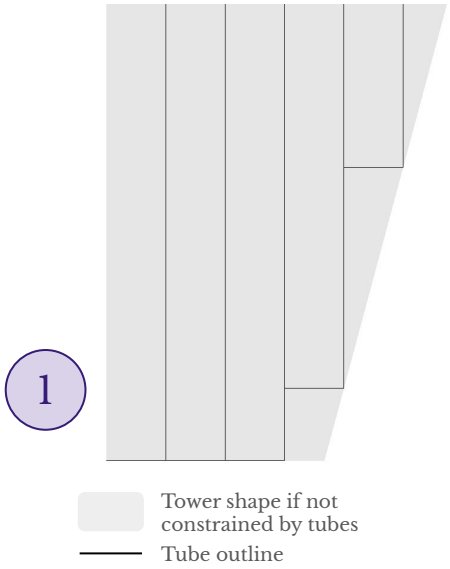
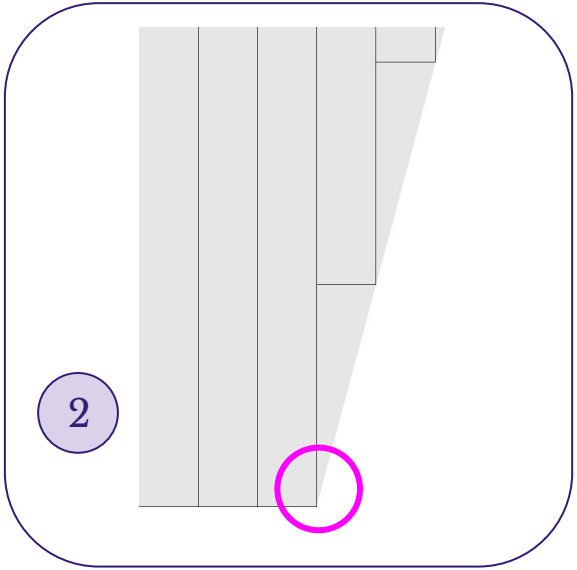
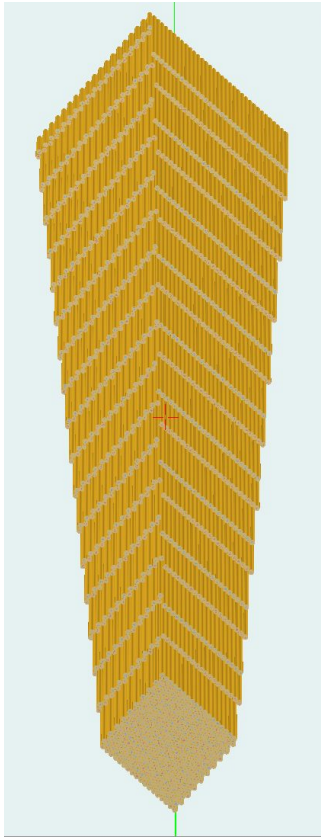
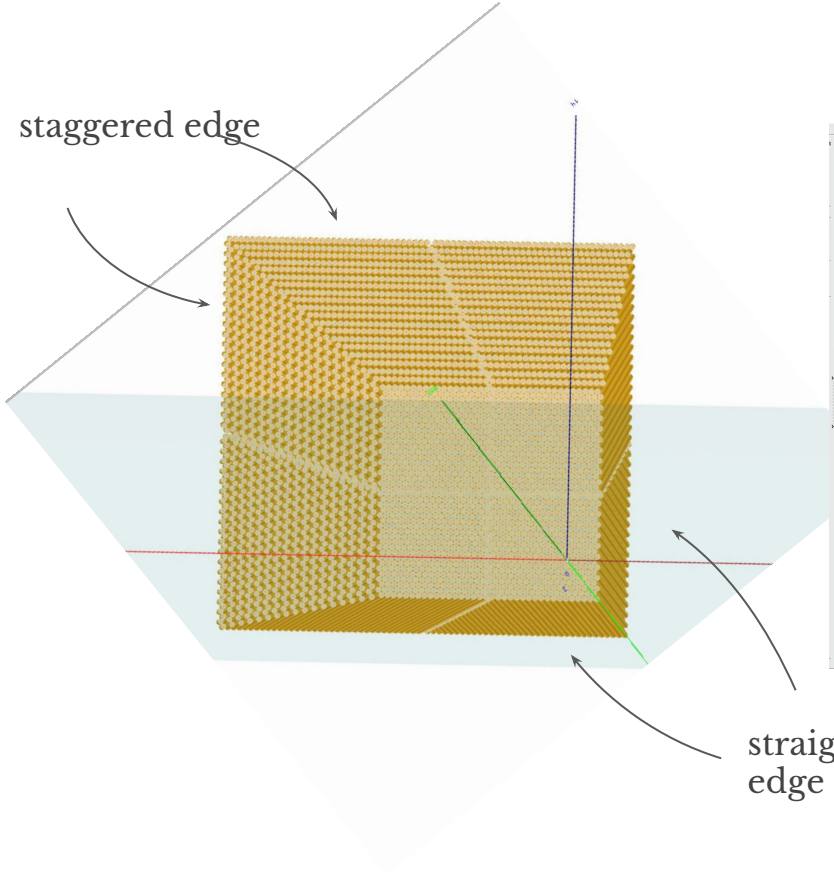


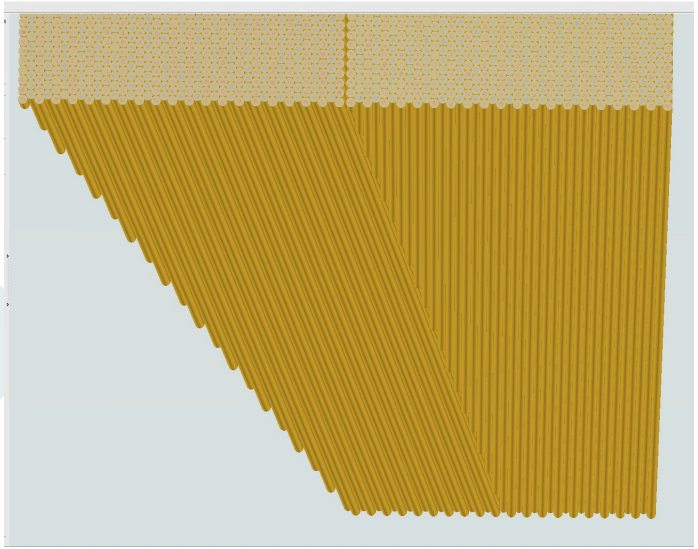
- Allow for tower size variation to have whole number of tubes
  - Not same θ for every tower
- Minimises gaps in front face region



Tower in DD4hep

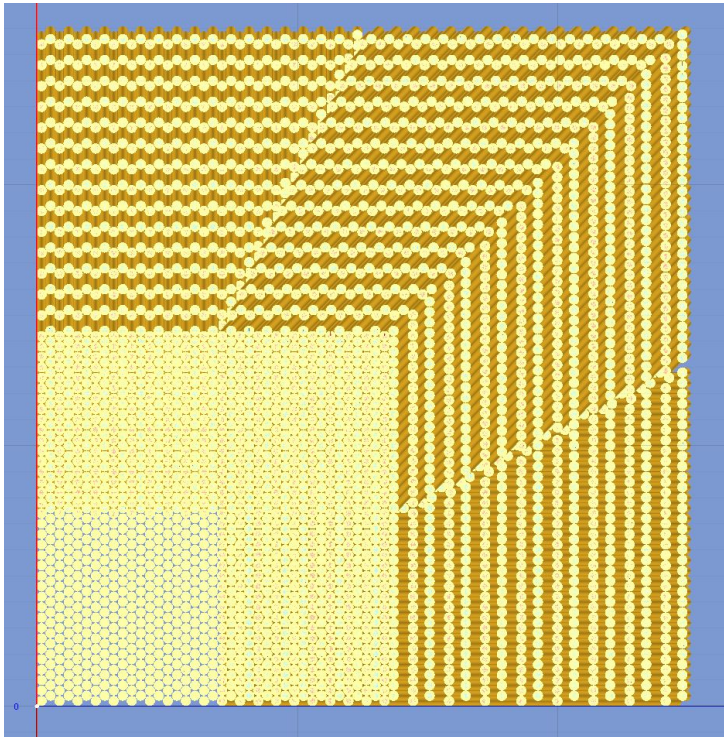




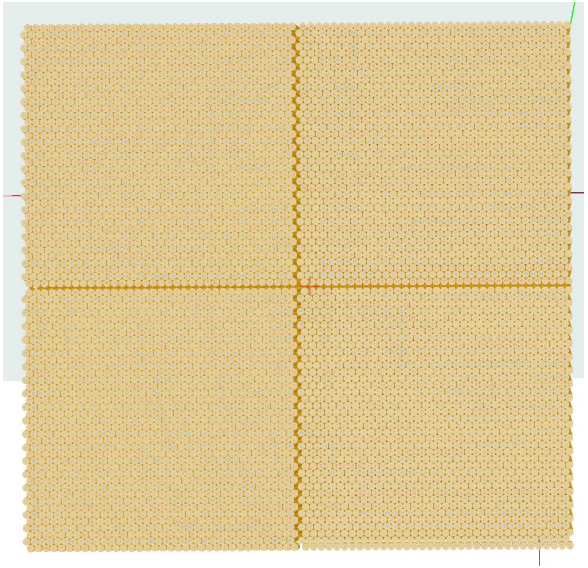


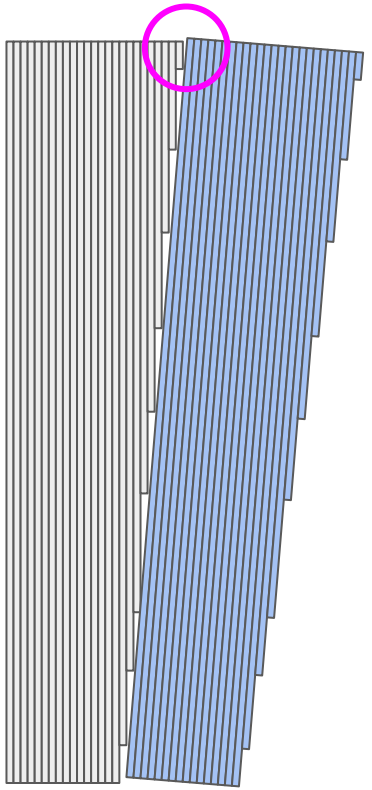
Tower in DD4hep

front



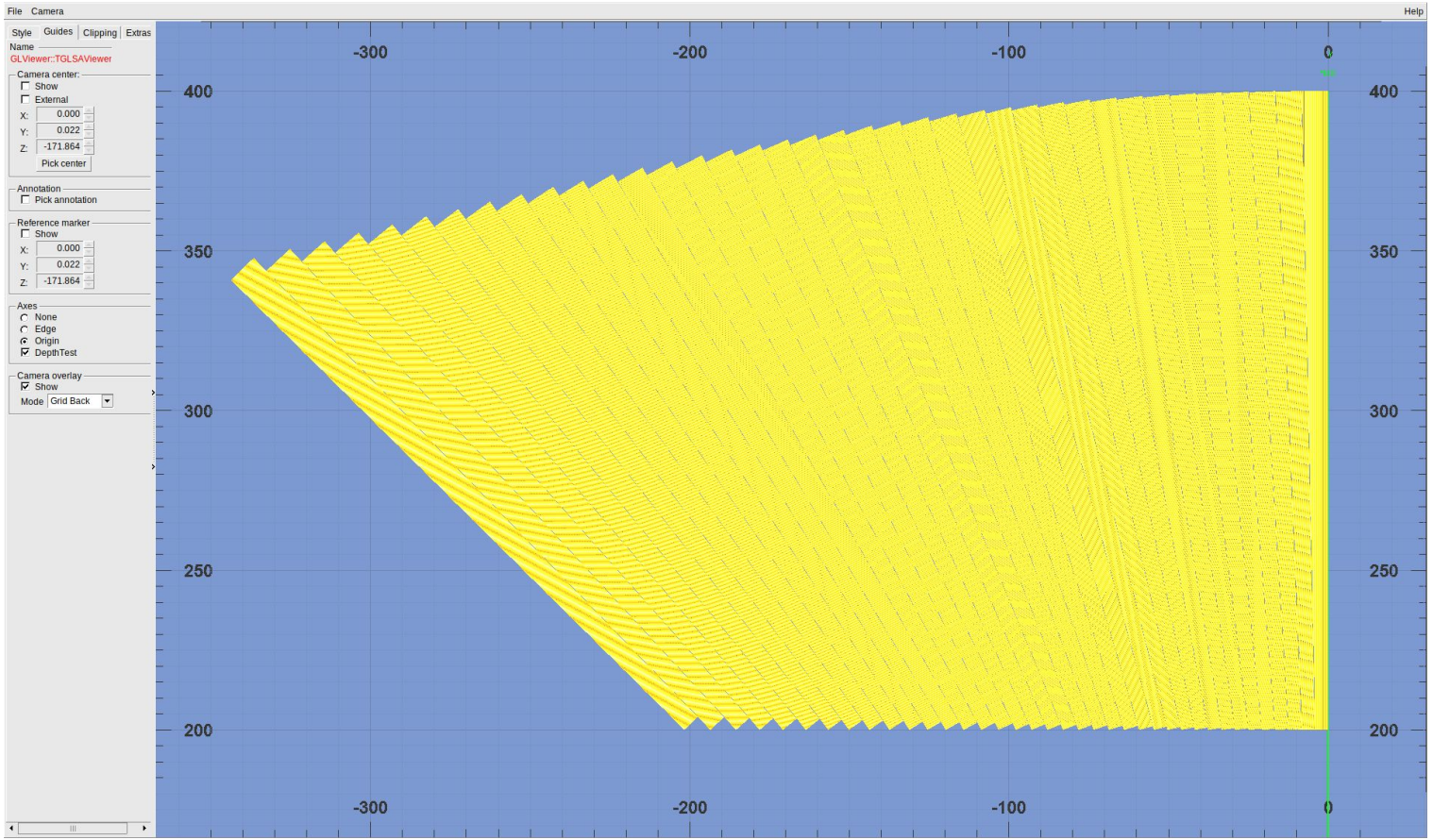
back





- Gap in back-face where no new fibres can be fit
- No gap in front-face
  (Unrealistic due to support structure)

Tower Placement: θ direction



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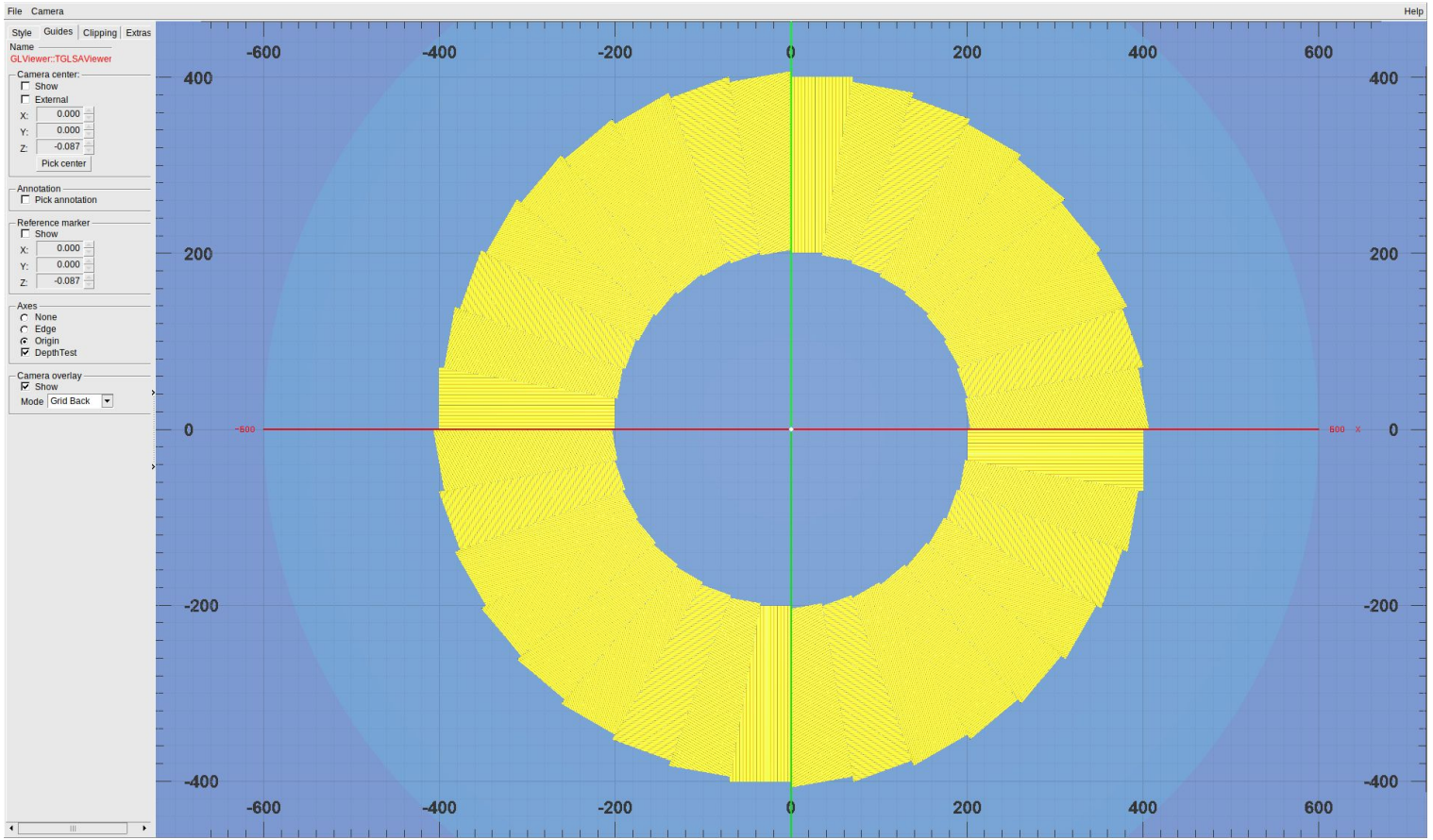
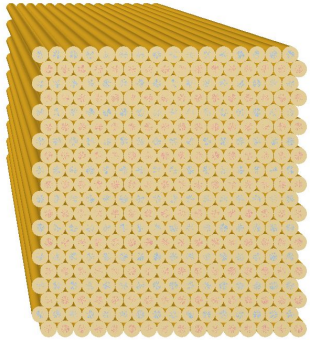
Tower Placement: φ direction



DD4hep implementation in C++



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- Tower constructed as Assembly

```
Assembly       module_volume(det_name+"_module");
```

  - No volume for stack of cylinders
- Tubes are added to Assembly one-by-one
- Tower is constructed once for each θ and then repeatedly placed in φ (identical φ slices)

- Current parameters in xml file:

```
<constant name="FibreOuterRadius" value="0.485*mm"/>
<constant name="CladOuterRadius"  value="0.5*mm"  />
<constant name="TubeOuterRadius"  value="1.0*mm"  />

<constant name="InnerCaloRadius"     value="2.0*m"  />
<constant name="InnerCaloHalfLength" value="2.0*m"  />
<constant name="TowerHalfLength"     value="1*m"    />
<constant name="TowerThetaCoverage"  value="1.0*deg"/>
<constant name="TowerPhiCoverage"    value="1*deg"  />
```

Summary

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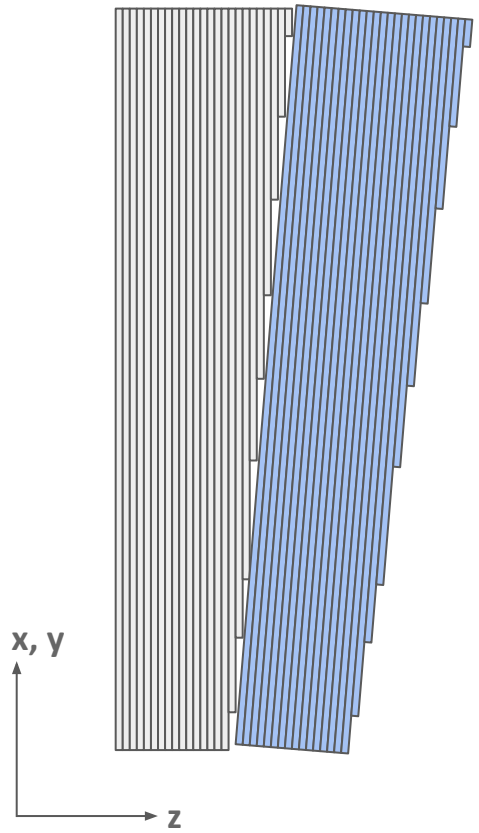
- Tower construction with two straight edges and two staggered ones
- Considerations for Bucatini layout (maybe) different from other geometries
  - Constrained by integer number of tubes in calorimeter front-face
  - Gaps in geometry big concern
- Performance cost of large number of fibres is a concern

- So far only barrel region, need to look at endcaps next
- Only geometry, no signal generation yet

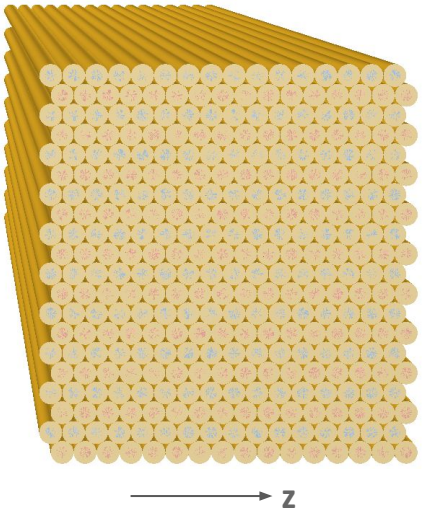
Backup Slides

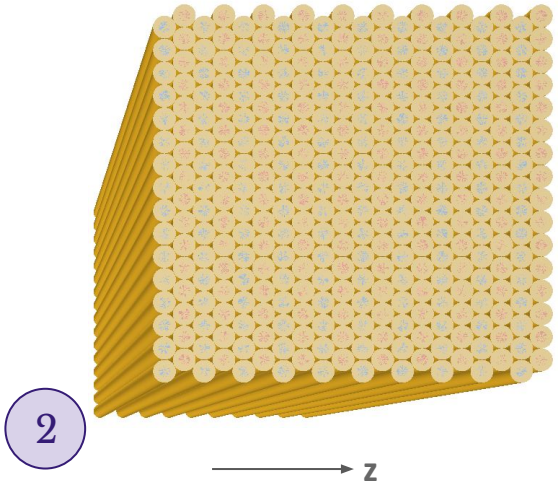
Constructing a Tower



Orientation of the tubes:

- Likely not a large difference
- Same considerations either in θ or φ
- Decided for option **2**
  - "Straight" edge in θ direction





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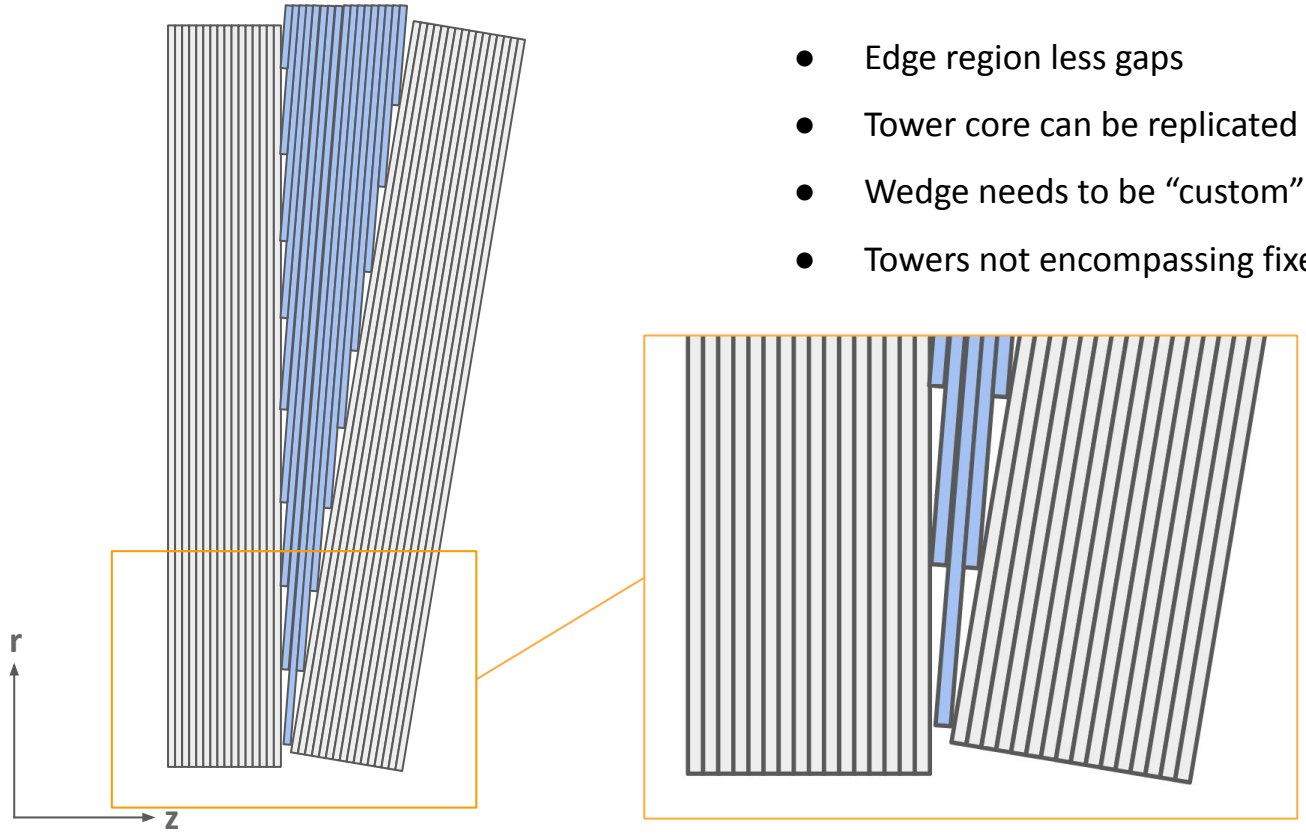
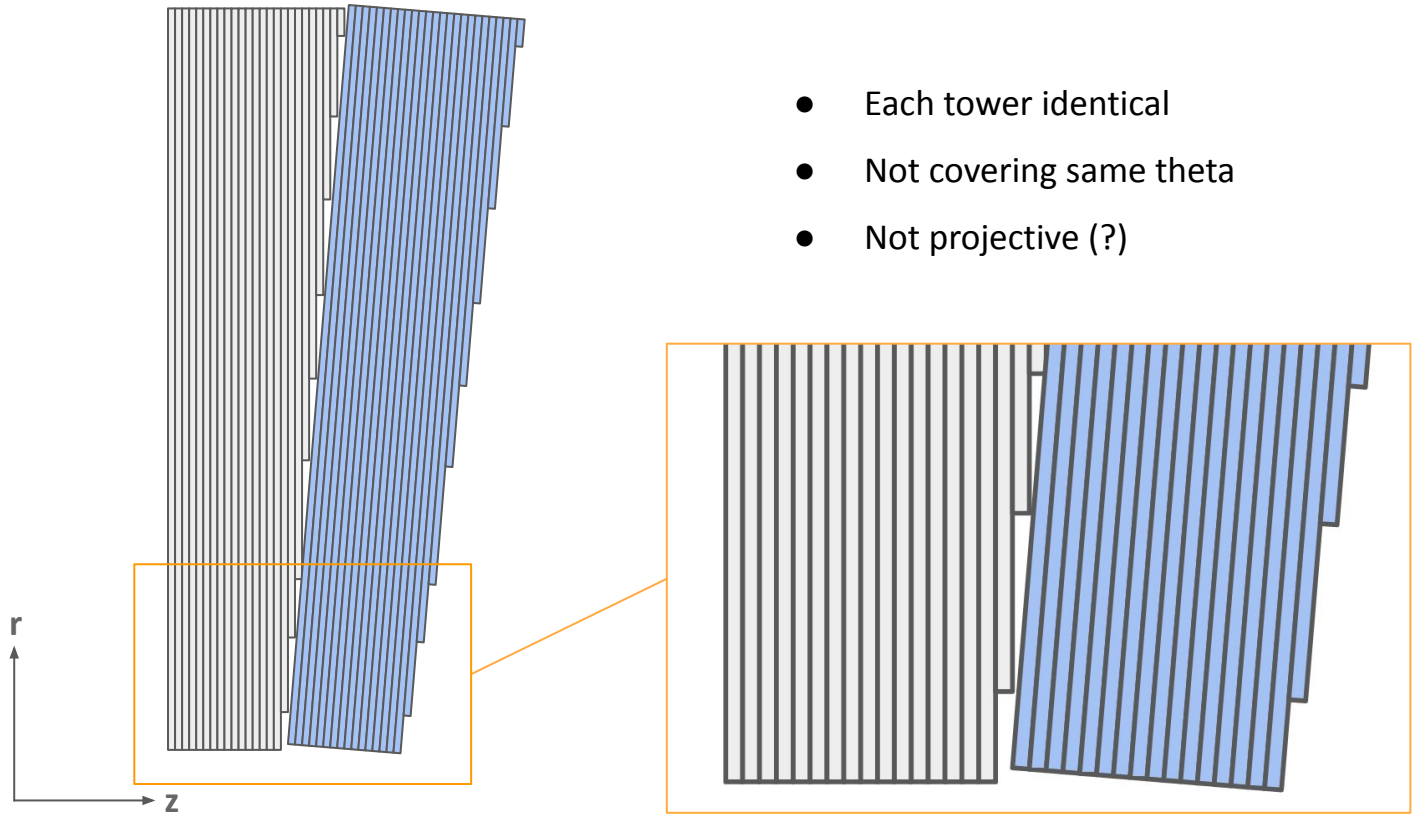


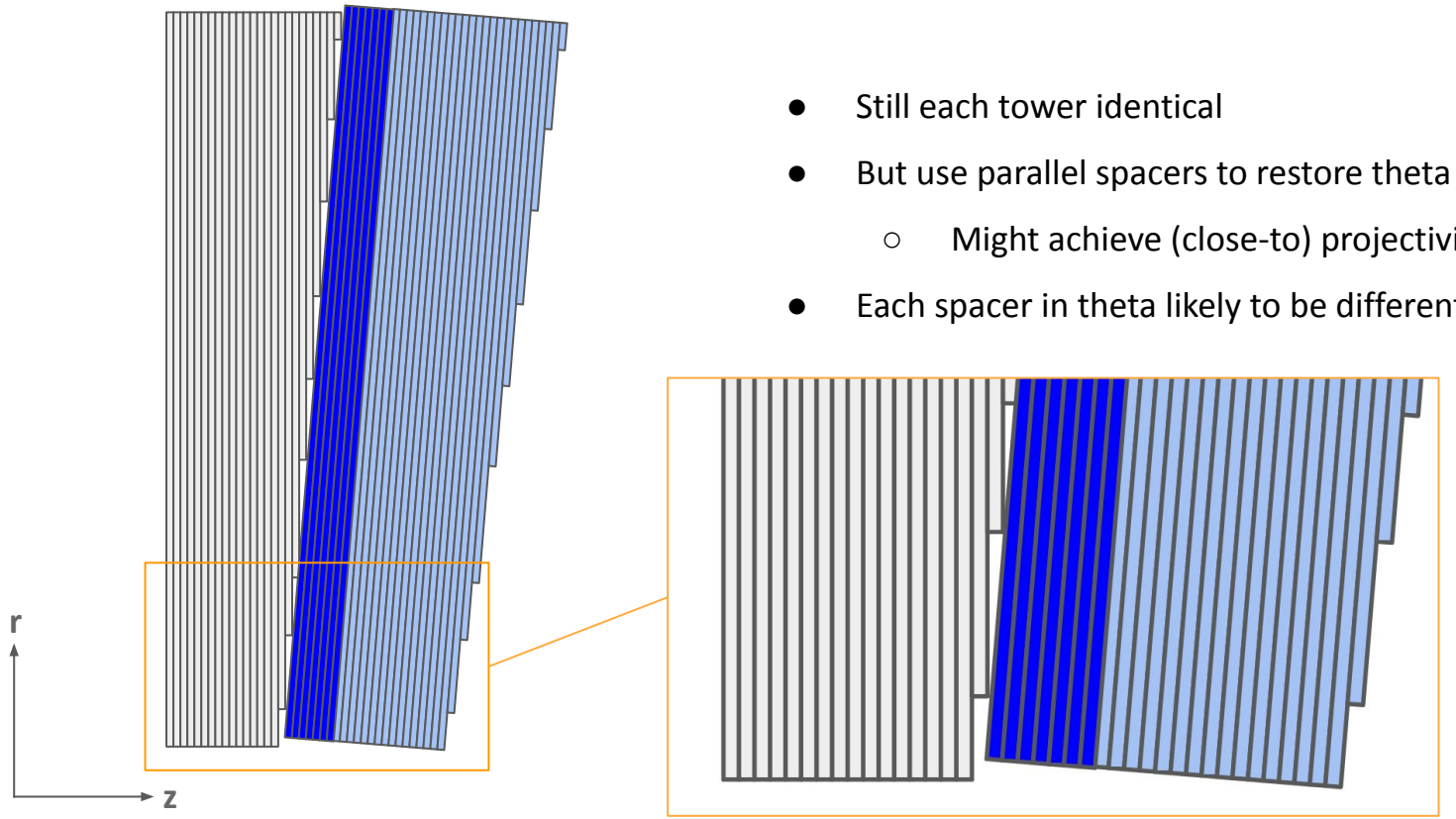
- Edge region less gaps
- Tower core can be replicated easily
- Wedge needs to be “custom”
- Towers not encompassing fixed theta

How to build projective towers with tubes?



- Each tower identical
- Not covering same theta
- Not projective (?)

How to build projective towers with tubes?



- Still each tower identical
- But use parallel spacers to restore theta difference
  - Might achieve (close-to) projectivity
- Each spacer in theta likely to be different