

# A cover to protect the KOTO Csl calorimeter from earthquakes

---

Taku Yamanaka

December 19, 2011

Kuno-Yamanaka Group Year-end Meeting



# KOTO Csl Calorimeter

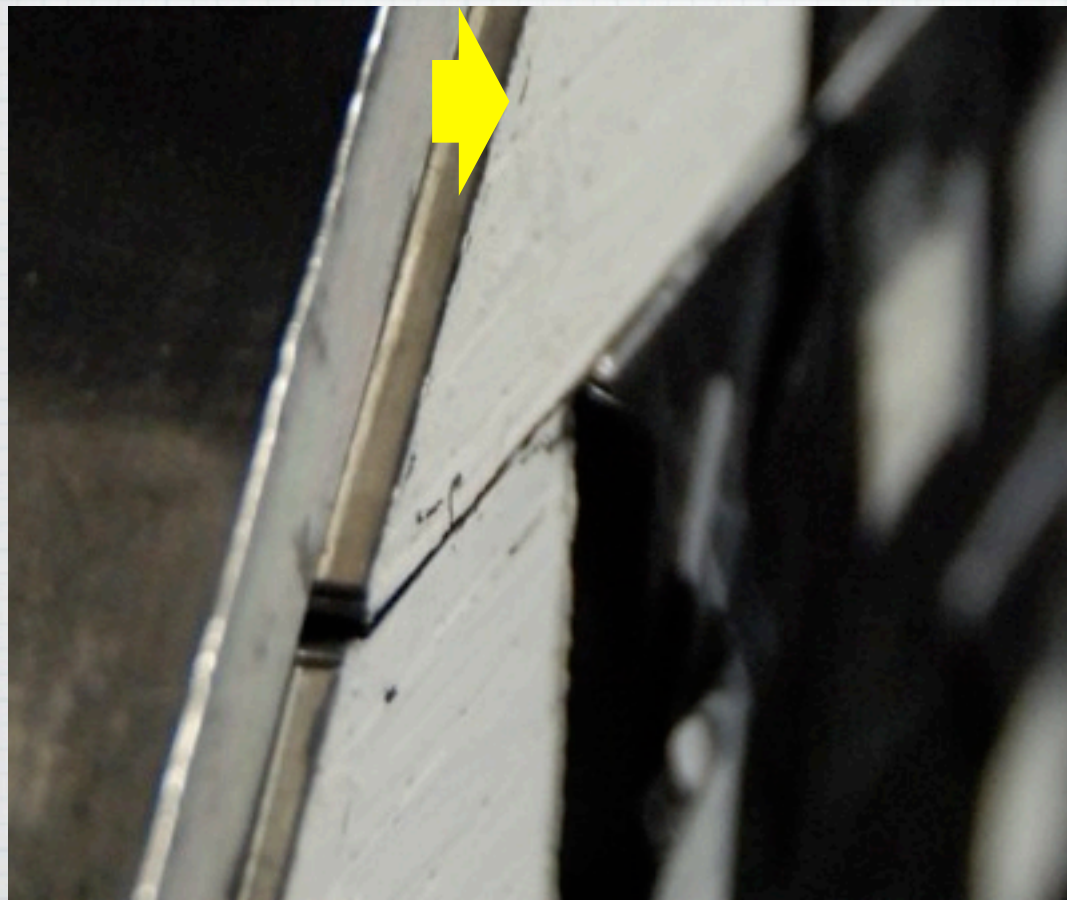
- \* 2240 2.5cm x 2.5cm
- \* 476 5cm x 5cm
- \* 50cm long Csl crystals
- \* Finished stacking on Feb. 10, 2011





# The Earthquake

- \* moved the Csl crystals out by ~5mm

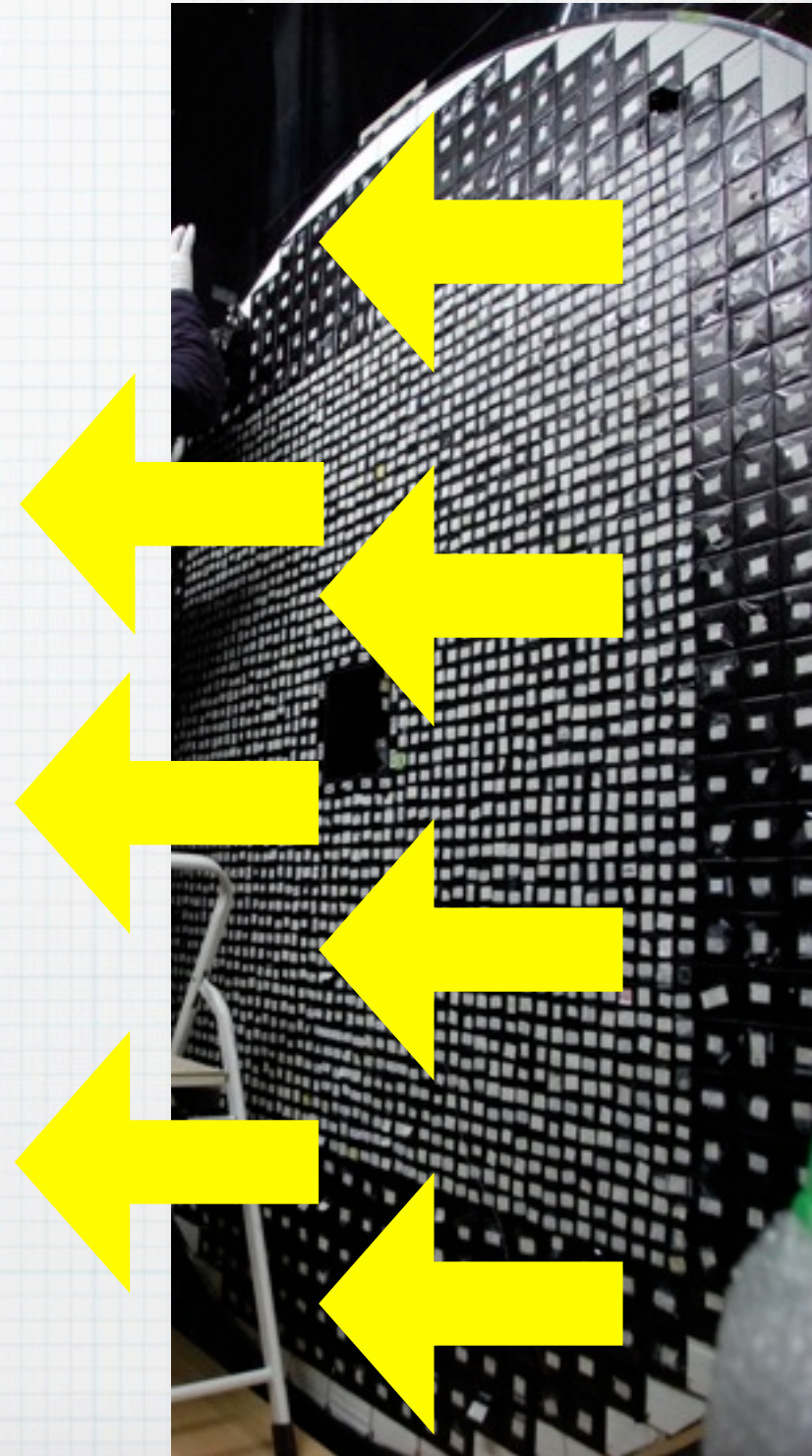




How do we prevent  
the crystals from  
*flying out* when the  
next large earthquake  
comes?

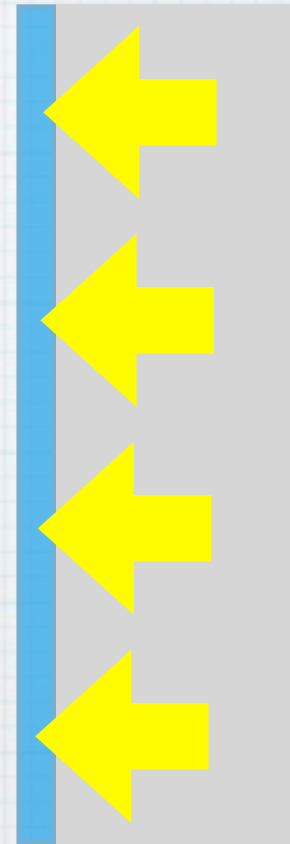
# Assumptions

- \* 1 G horizontal acceleration
- \*  $4.5\text{g/cm}^3 \times 50\text{cm} \times 9.8\text{m/s}^2 = 22\text{kPa}$  side pressure
- \* x3 safety factor = **66kPa**  
(20t on 2m-diameter surface)

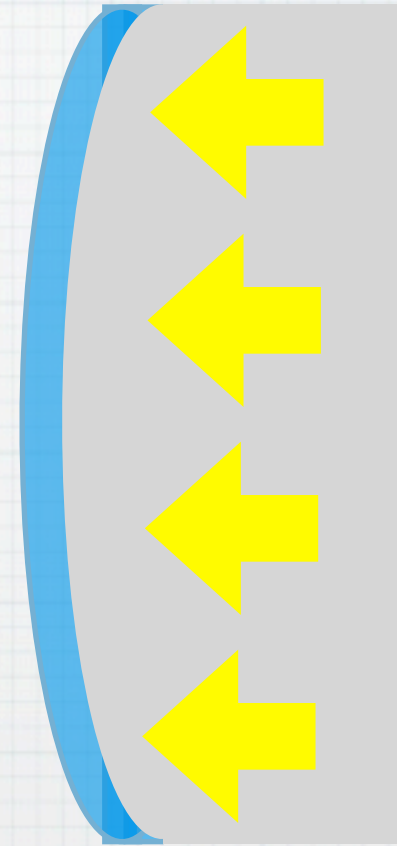




# Bending-force of a hard plate?



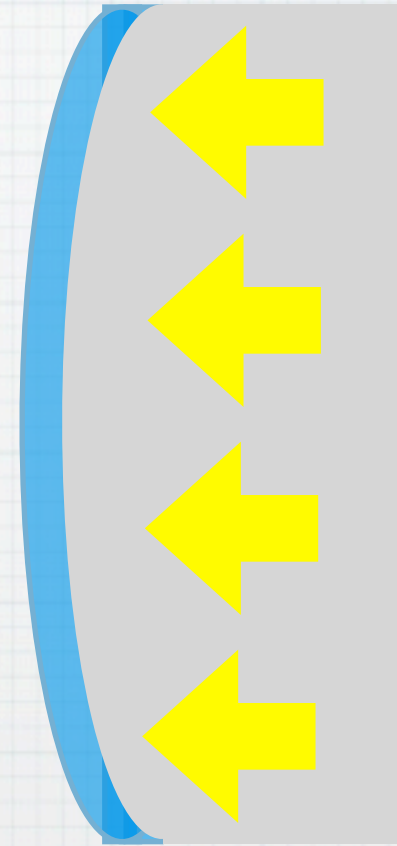
# Bending-force of a hard plate?





# Bending-force of a hard plate?

- \* Needs 2cm thick steel plate
- \* ~500 kg!





# Tension of a soft cloth?



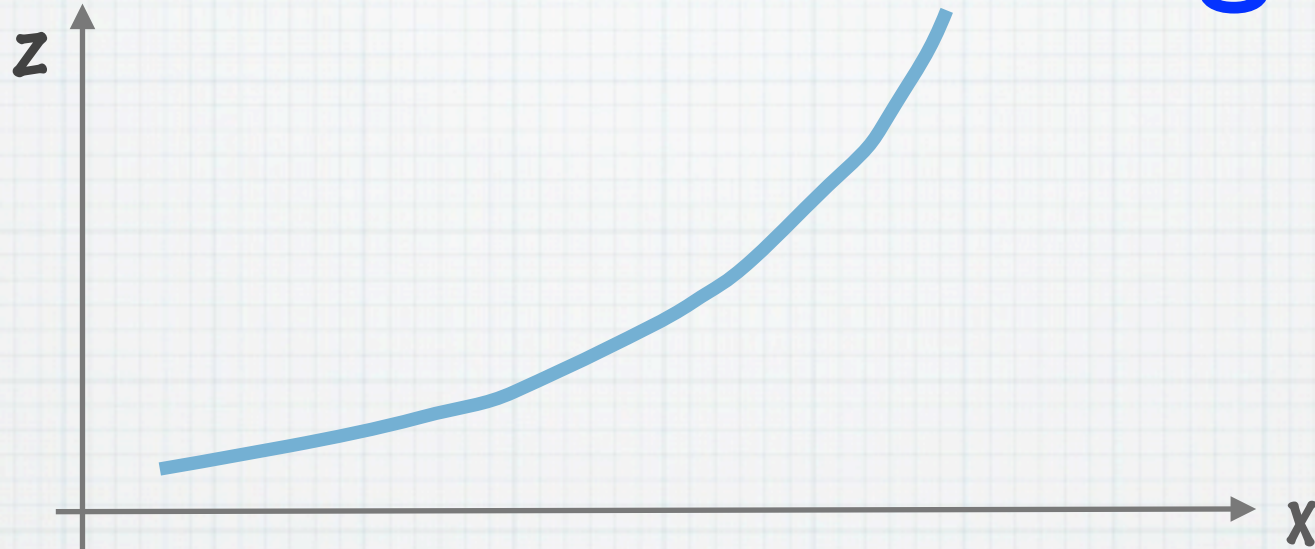
# Tension of a soft cloth?





# Tension and curvature

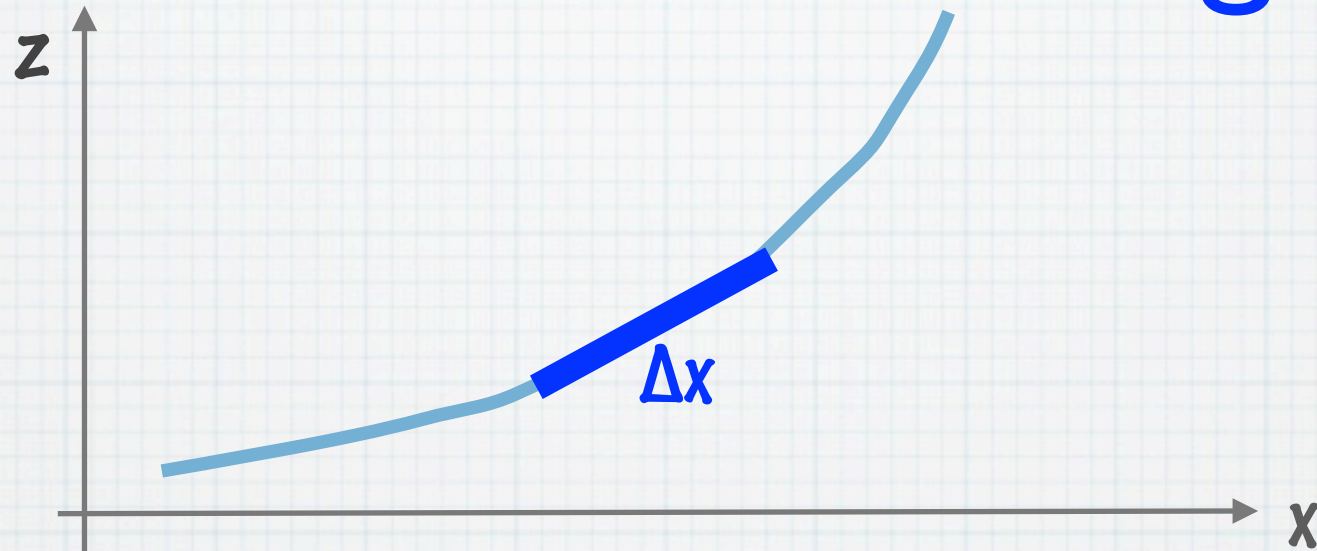
- in case of a string -





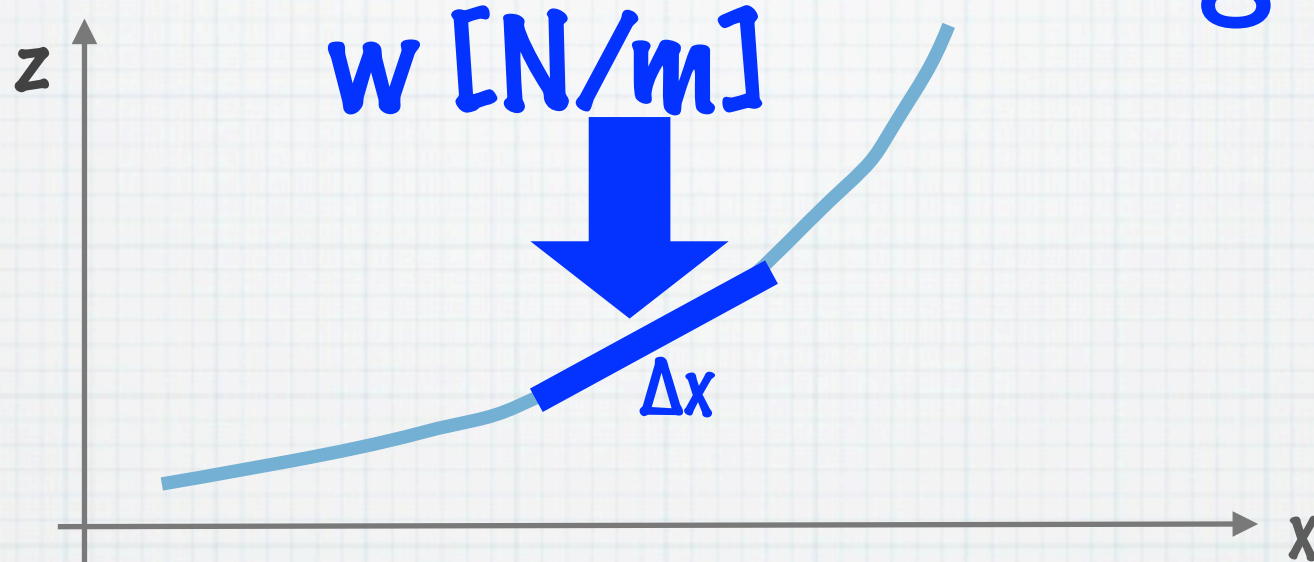
# Tension and curvature

- in case of a string -



# Tension and curvature

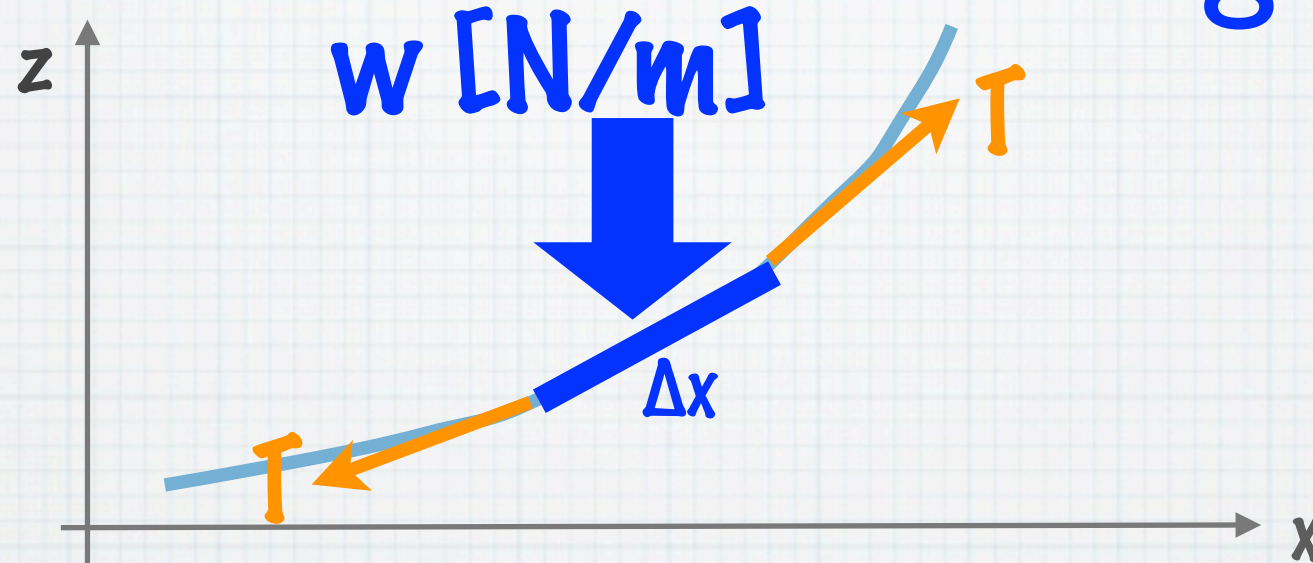
- in case of a string -





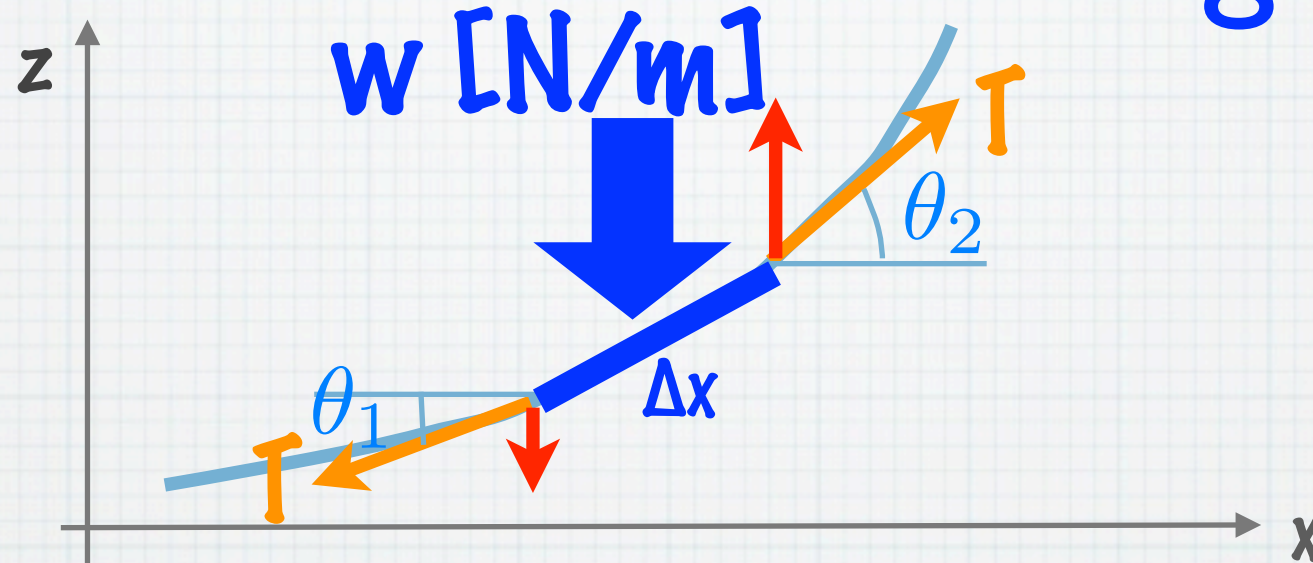
# Tension and curvature

- in case of a string -



# Tension and curvature

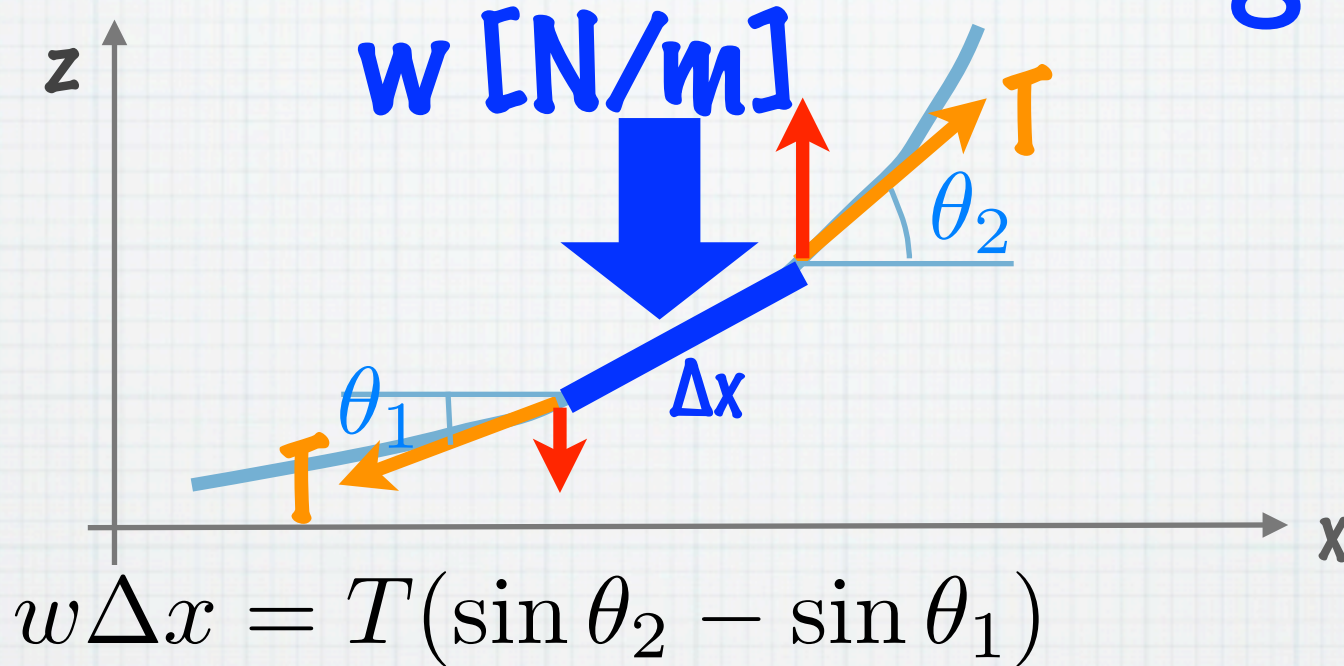
- in case of a string -





# Tension and curvature

- in case of a string -



$$w\Delta x = T(\sin \theta_2 - \sin \theta_1)$$

$$\simeq T\left(\frac{dz}{dx}(x + \Delta x) - \frac{dz}{dx}(x)\right)$$

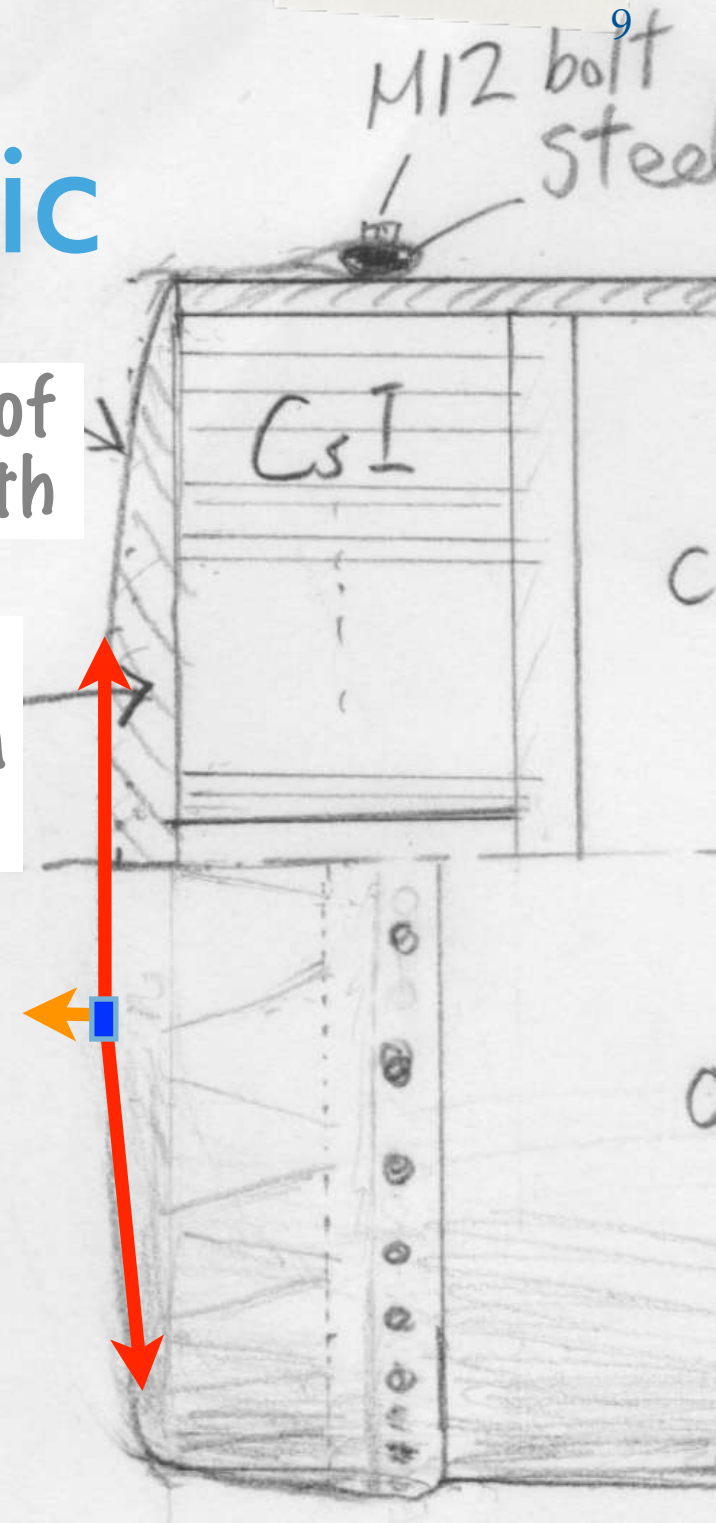
$$w \simeq T \frac{d^2 z}{dx^2}$$

# Aramid fabric

- \* Teijin Technora:  
 $T < 170 \text{ kN/m}$
- \* Curvature with 10cm bulging can hold the weight
- \* ... but only 1m wide

Cover made of a strong cloth

Structure to keep parabola shape

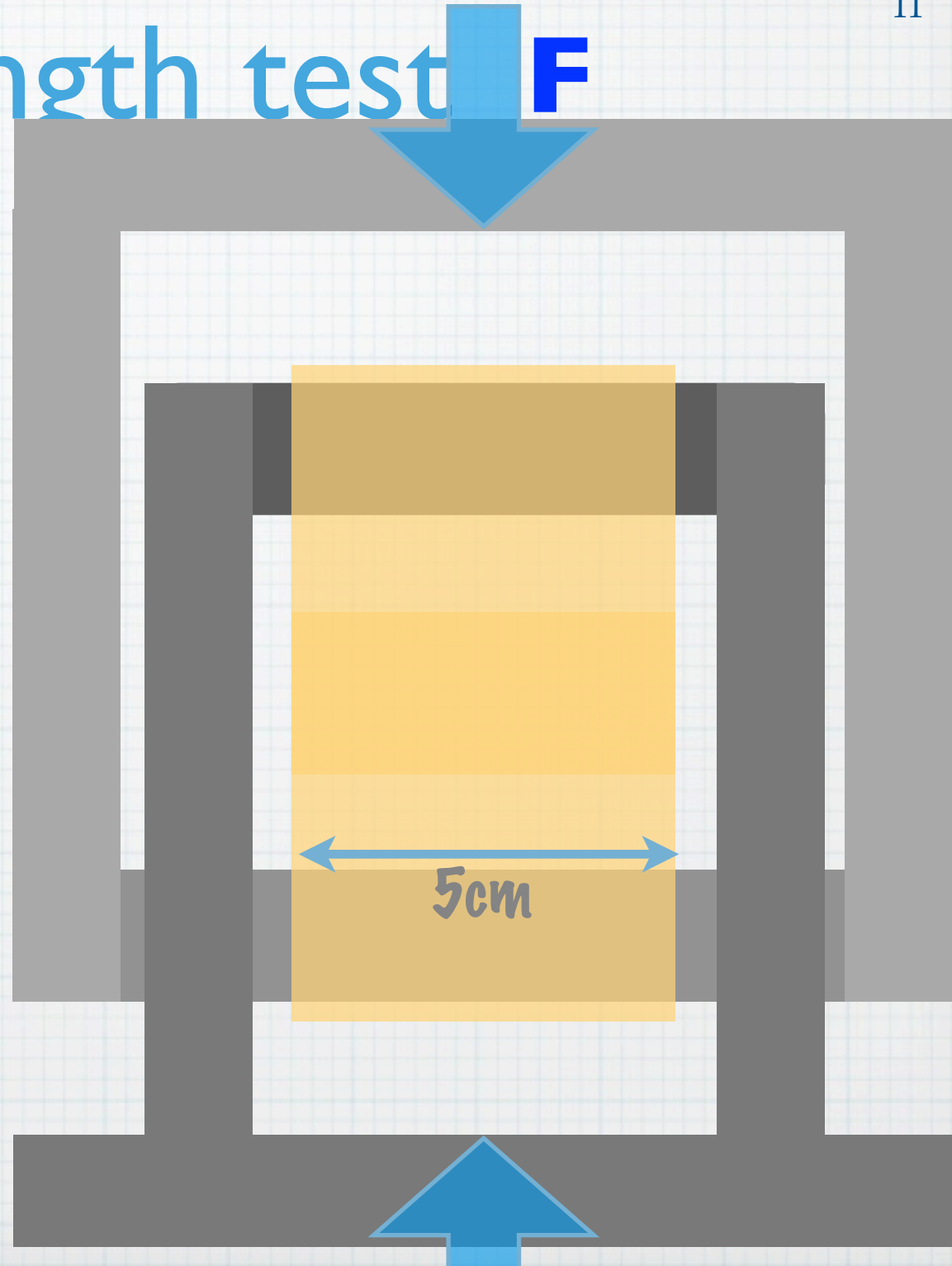




# How to sew fabrics together

# Strength test **F**

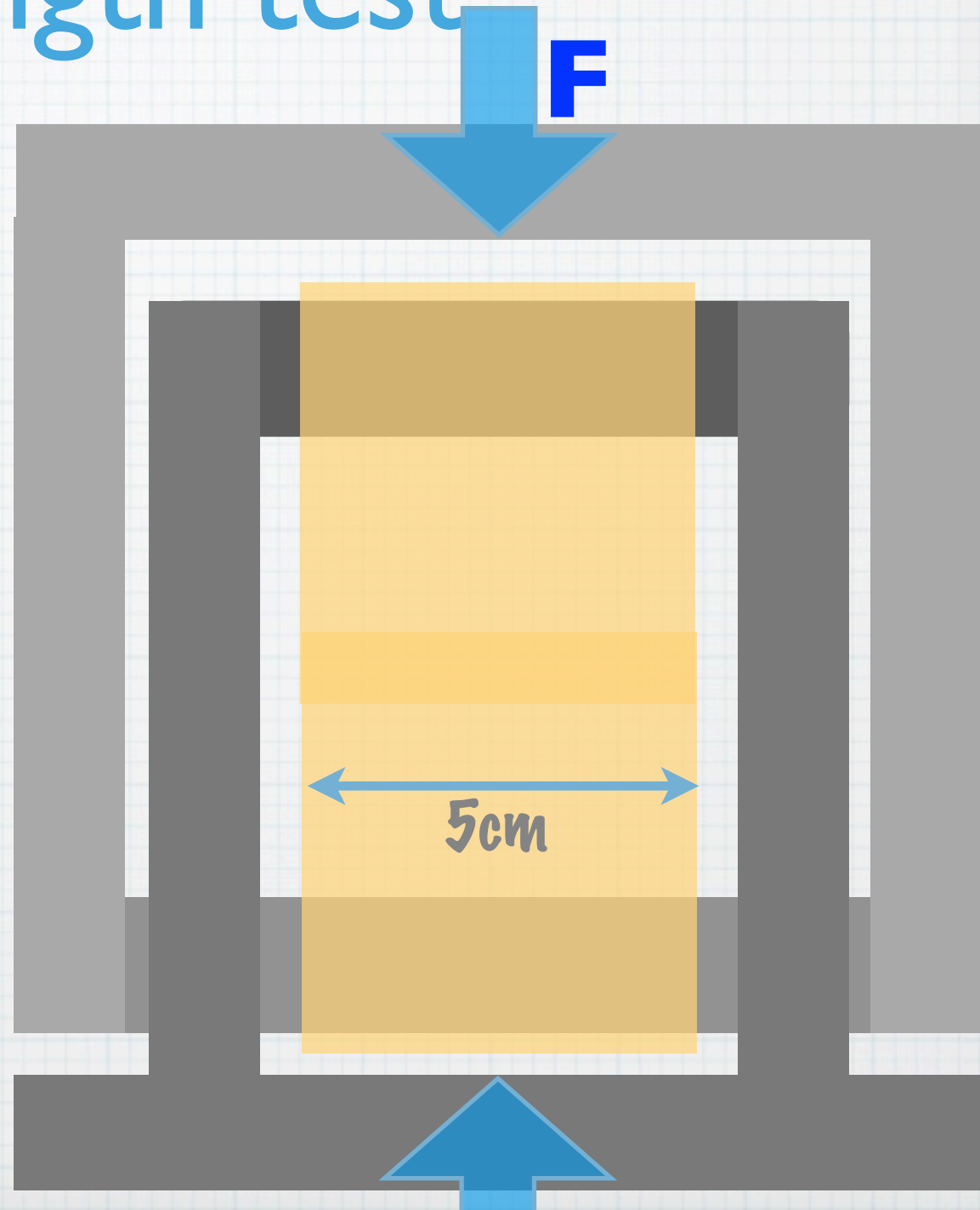
- \* Make a fabric loop with sewing
- \* Insert two bars inside the loop
- \* Press the two bars apart with force **F**
- \* Tension = **F**/2





# Strength test

- \* Make a fabric loop with sewing
- \* Insert two bars inside the loop
- \* Press the two bars apart with force  $F$
- \* Tension =  $F/2$









# Sample made by company





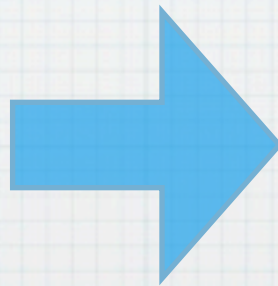
# Sample made by company

\* Tension

$\sim 3\text{kN}/5\text{cm}$

=  $60\text{kN}/\text{m}$

$< 170\text{kN}/\text{m}$   
(fabric strength)

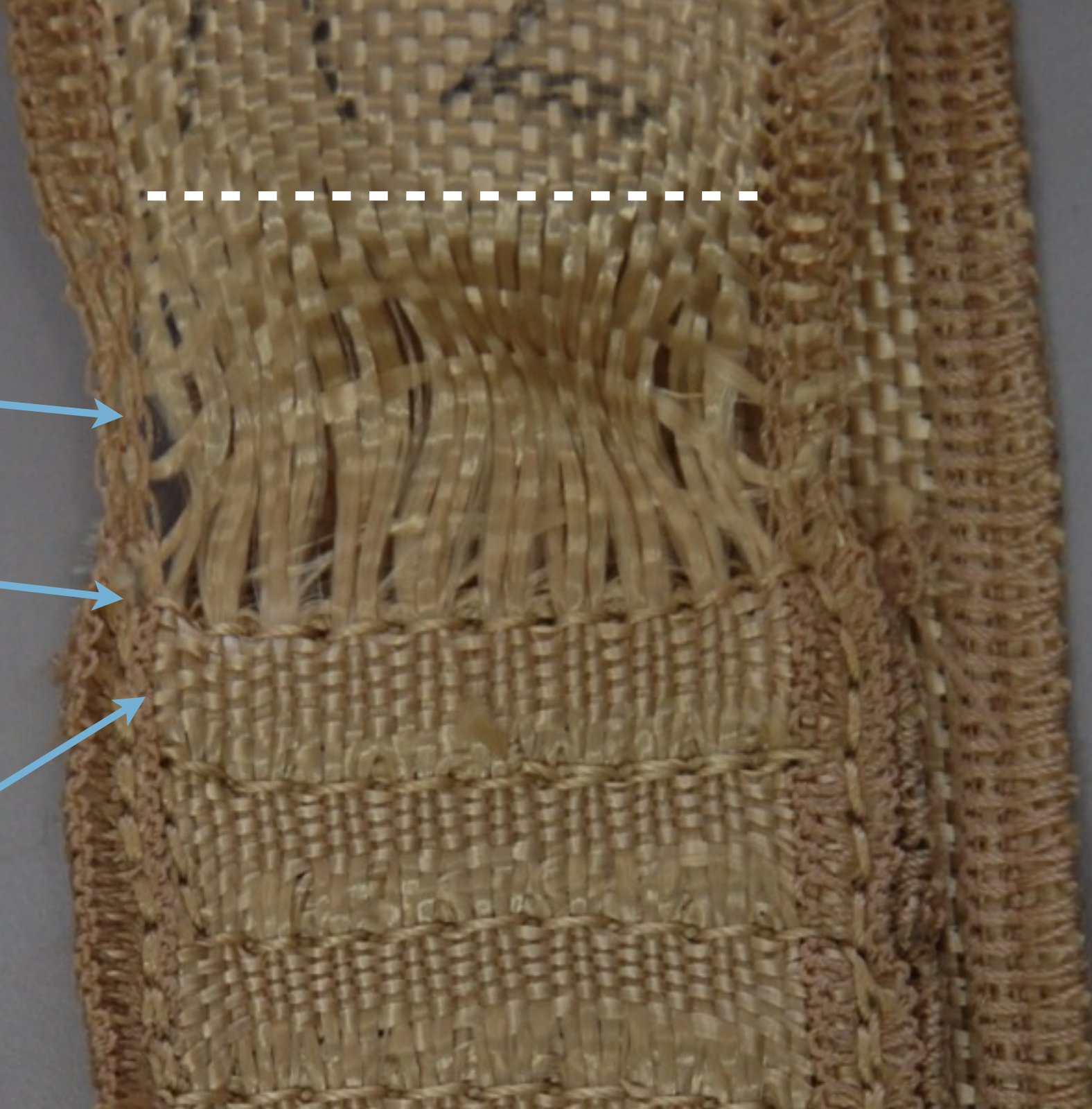




The weft slip.  
Warp only

Sewing thread  
push the weft

The weft are  
squeezed





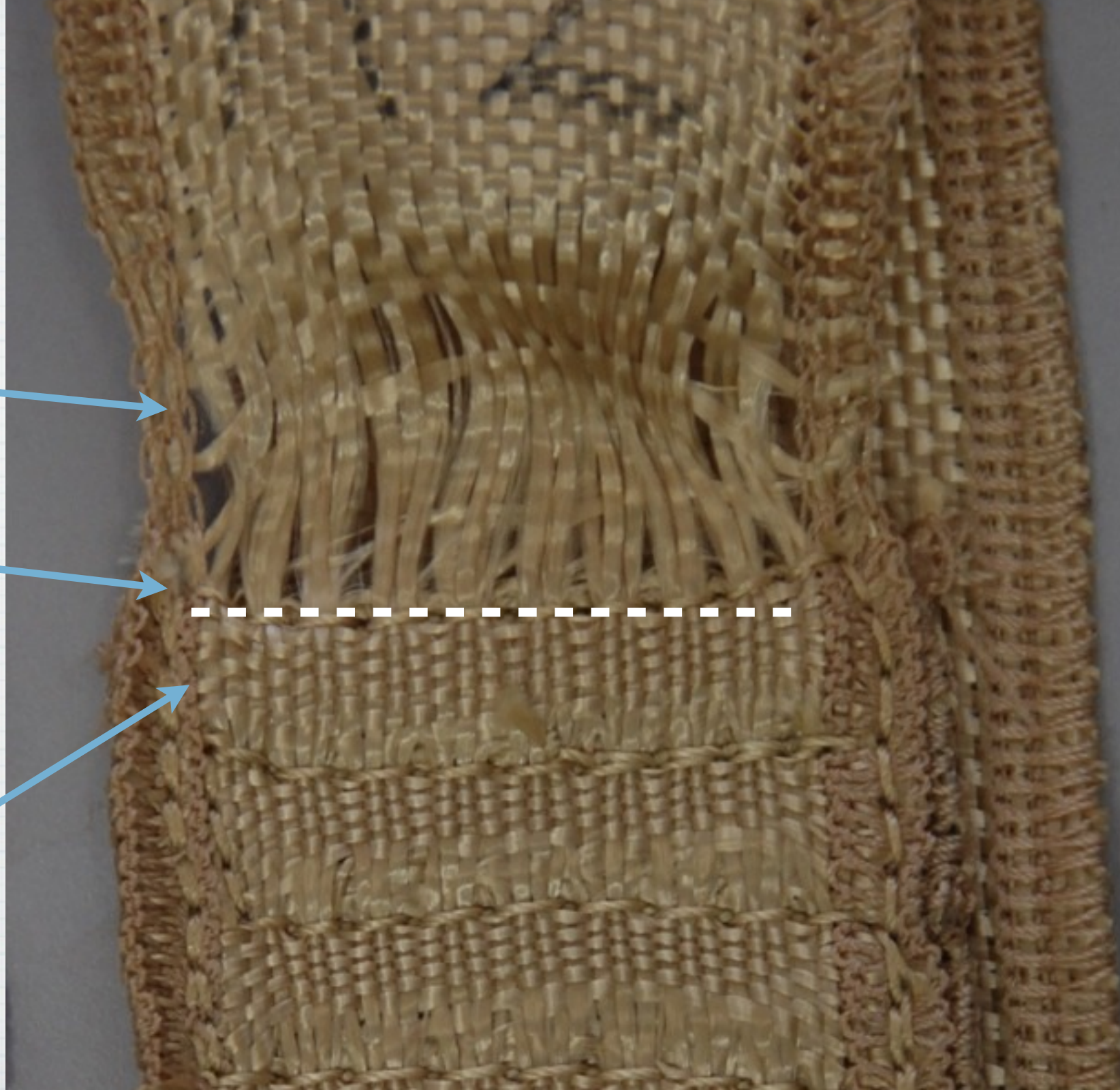
The weft slip.  
Warp only



Sewing thread  
push the weft



The weft are  
squeezed





# I tried many sewing methods



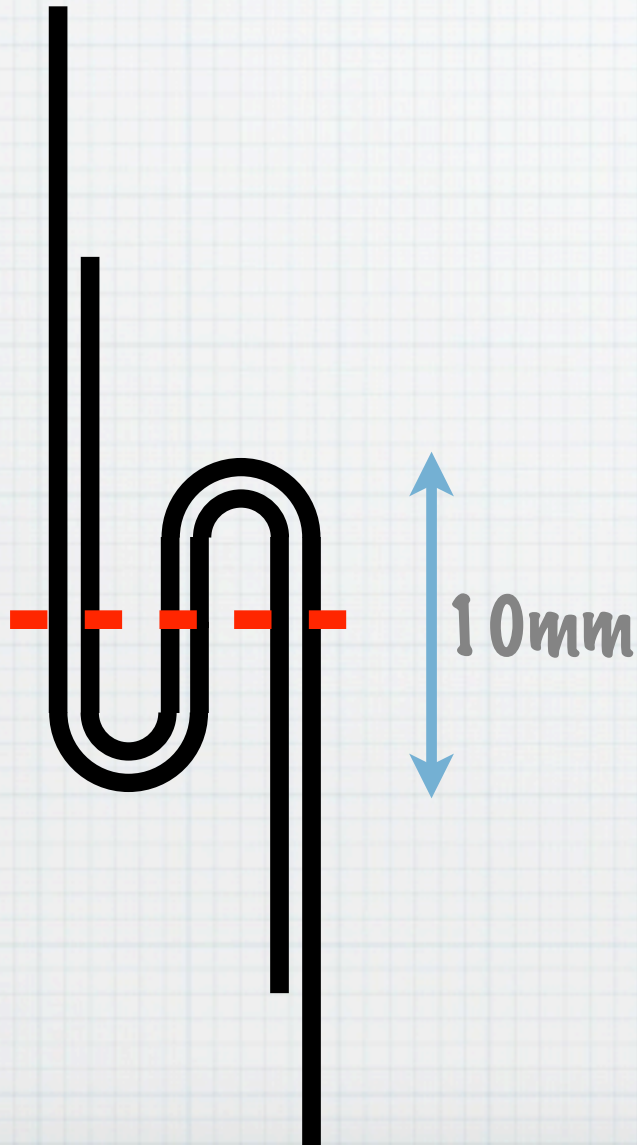






# Solution

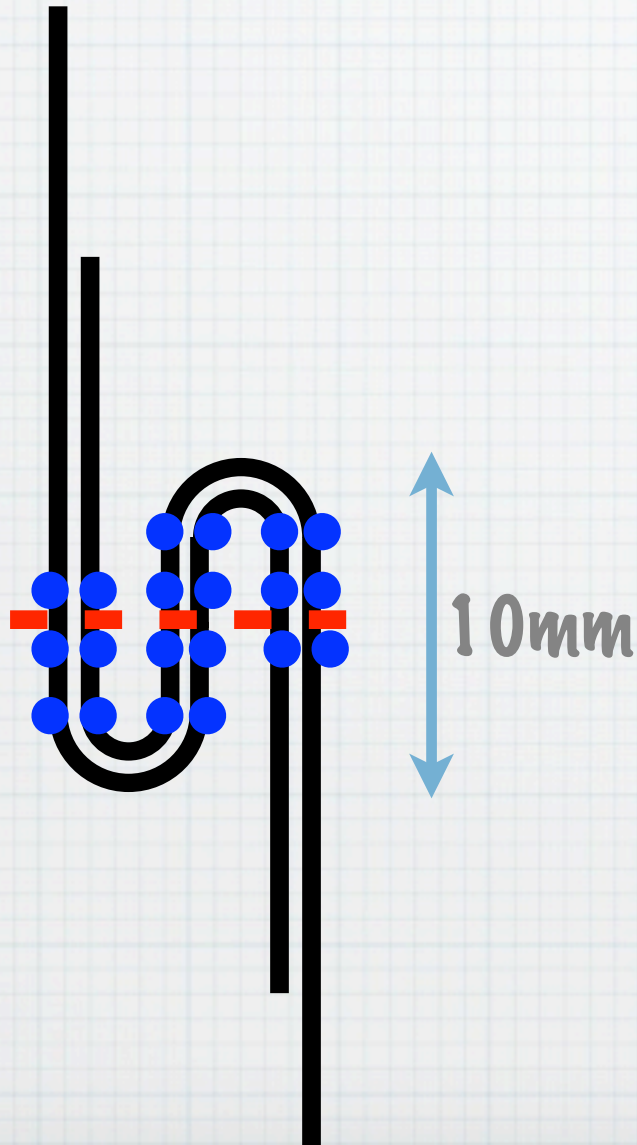
- \* Make dead ends for weft





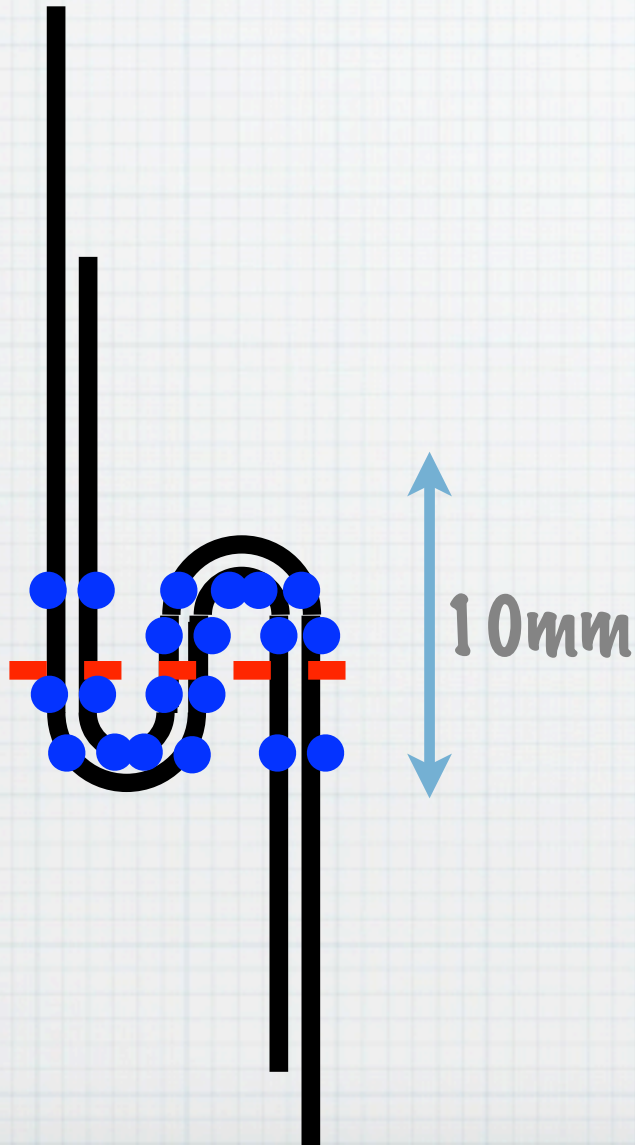
# Solution

- \* Make dead ends for weft



# Solution

- \* Make dead ends for weft

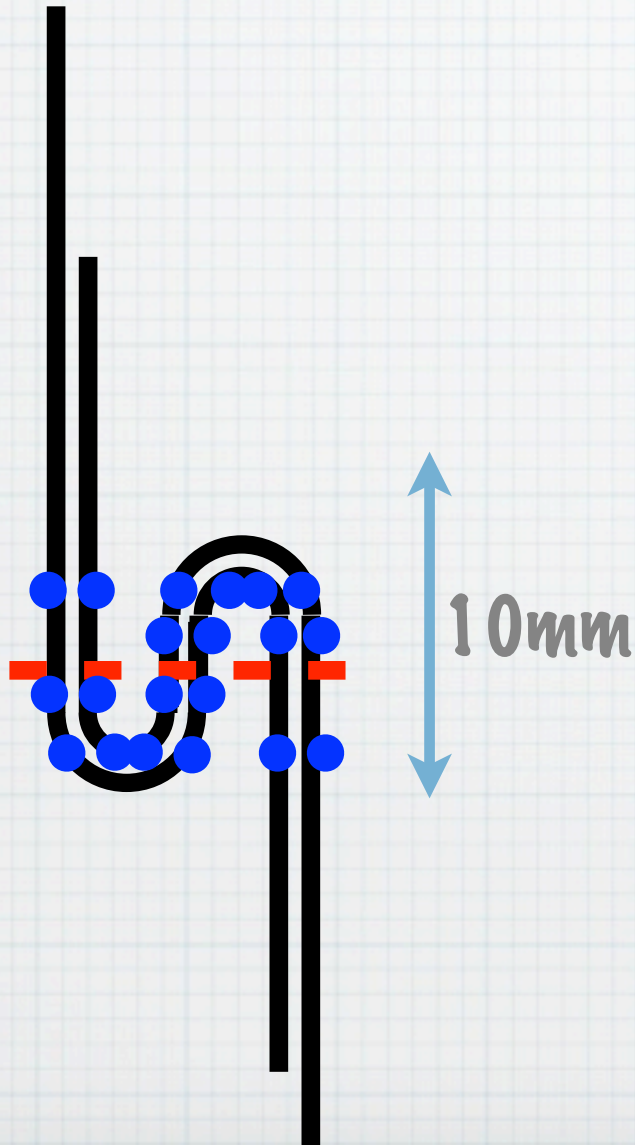




# Solution

\* Make dead ends for weft

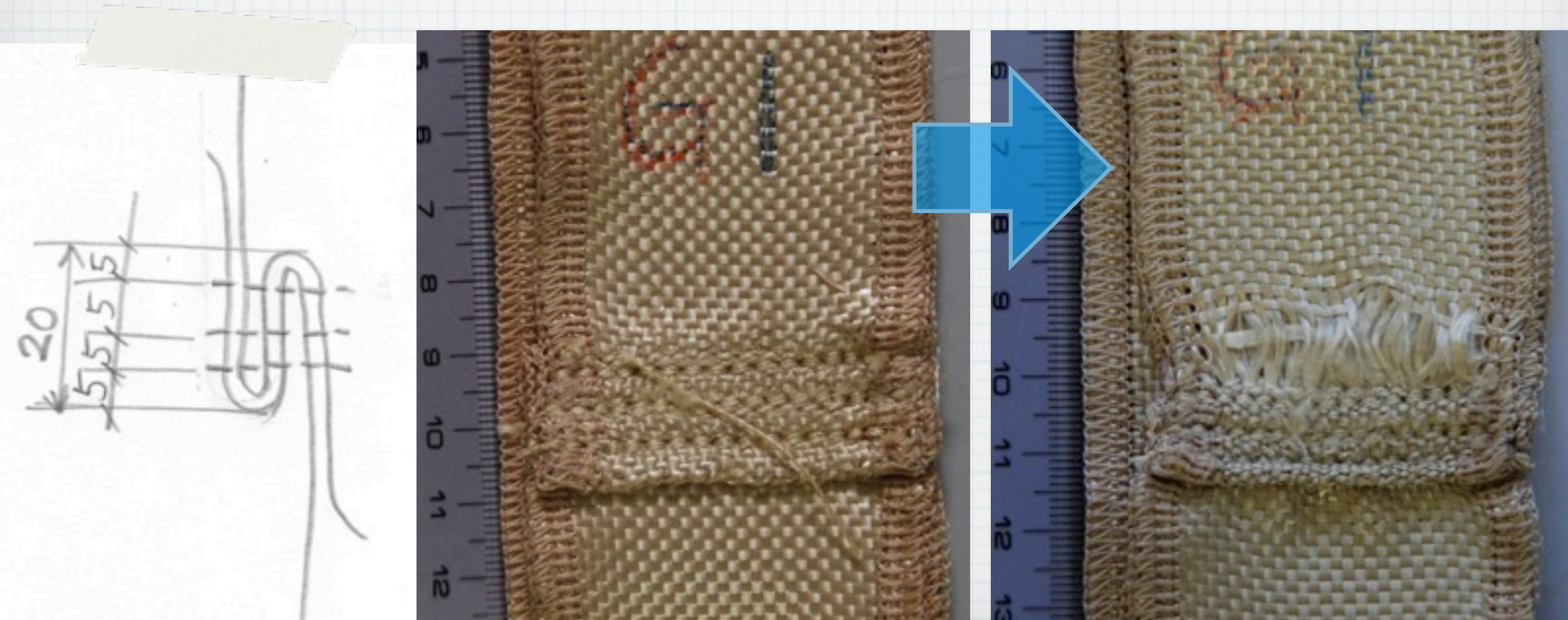
\* Tension  $\sim 100$  kN/m





# Final sewing method for Ver. I<sup>20</sup>

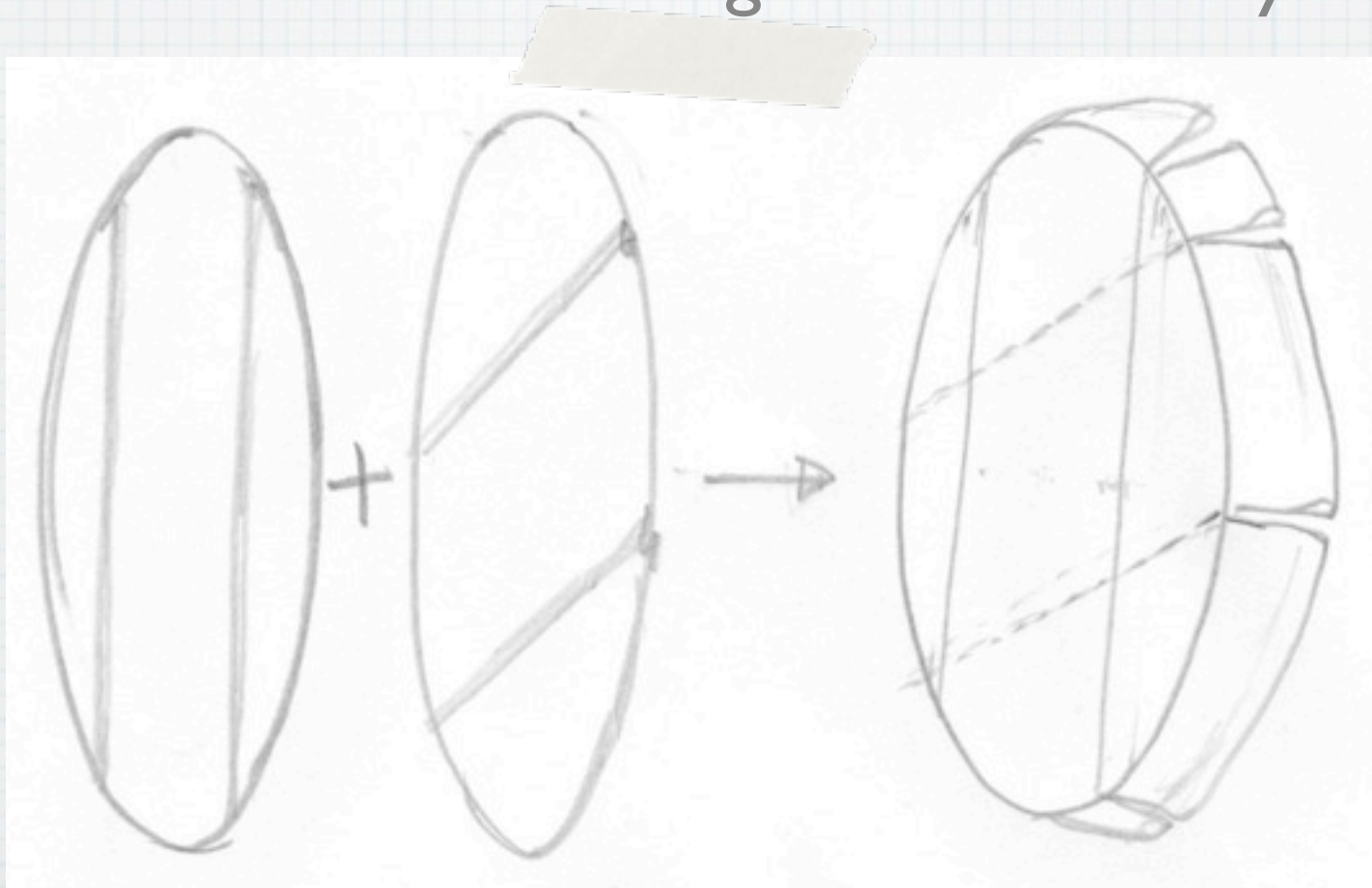
- \* Bend two fabrics together in Z-shape
- \* Sew 3 locations x 3 times w/ 3mm pitch
- \* Tension = **100 kN/m** = 0.6 x 170kN (fabric)





# Design

- \* Sew three 1m wide fabrics => 1 sheet
- \* 2 sheets at 45deg
- \* Add sides for securing down to the cylinder

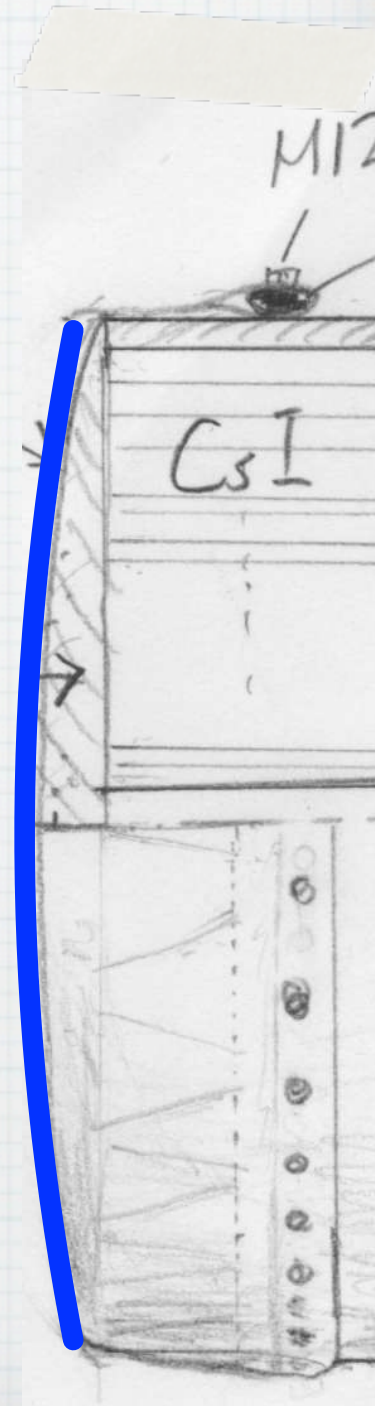


# The cover





# How to keep the parabola shape





# PVC pipes

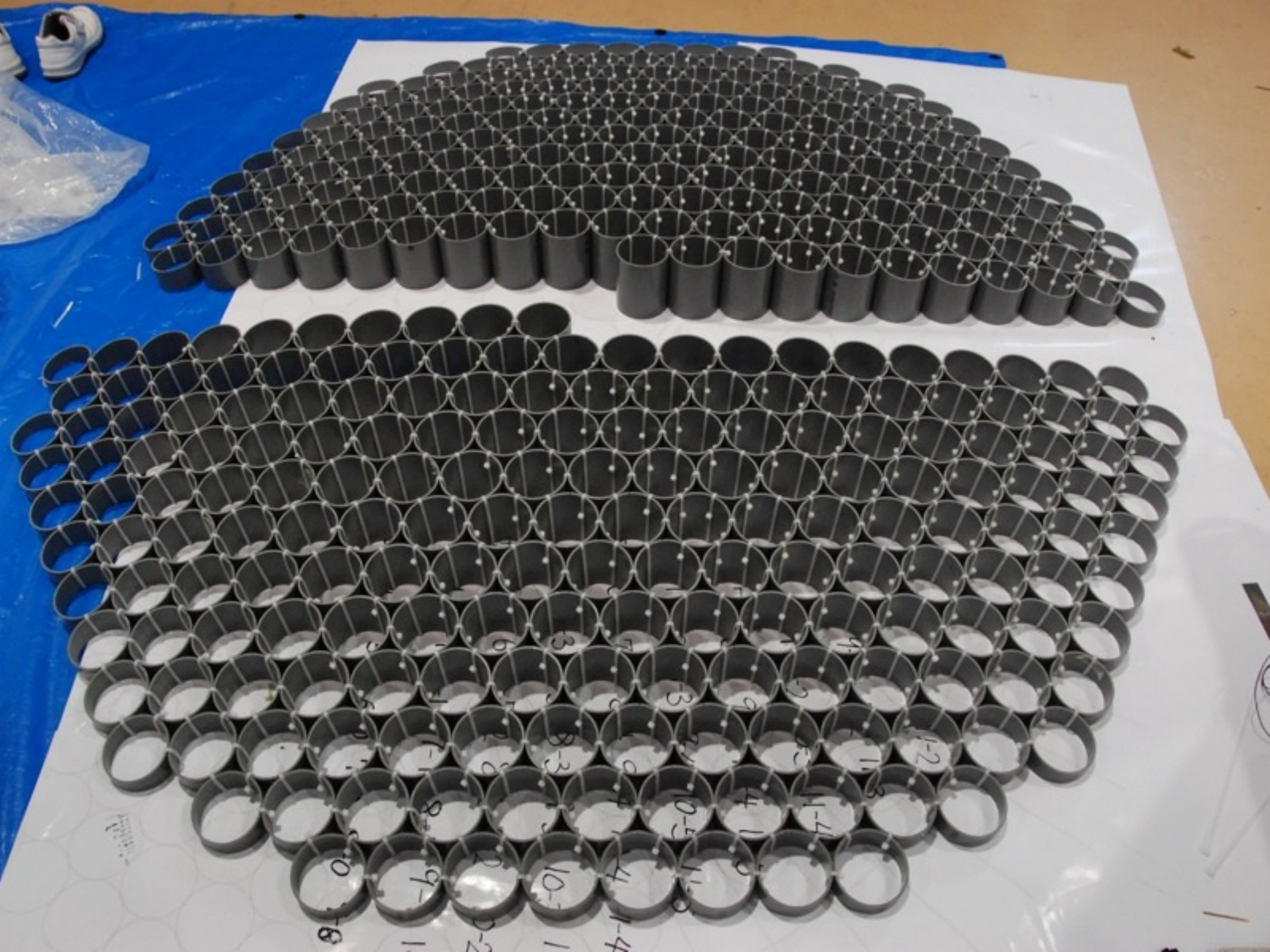
- \* 40 different types
- \* 379 pieces



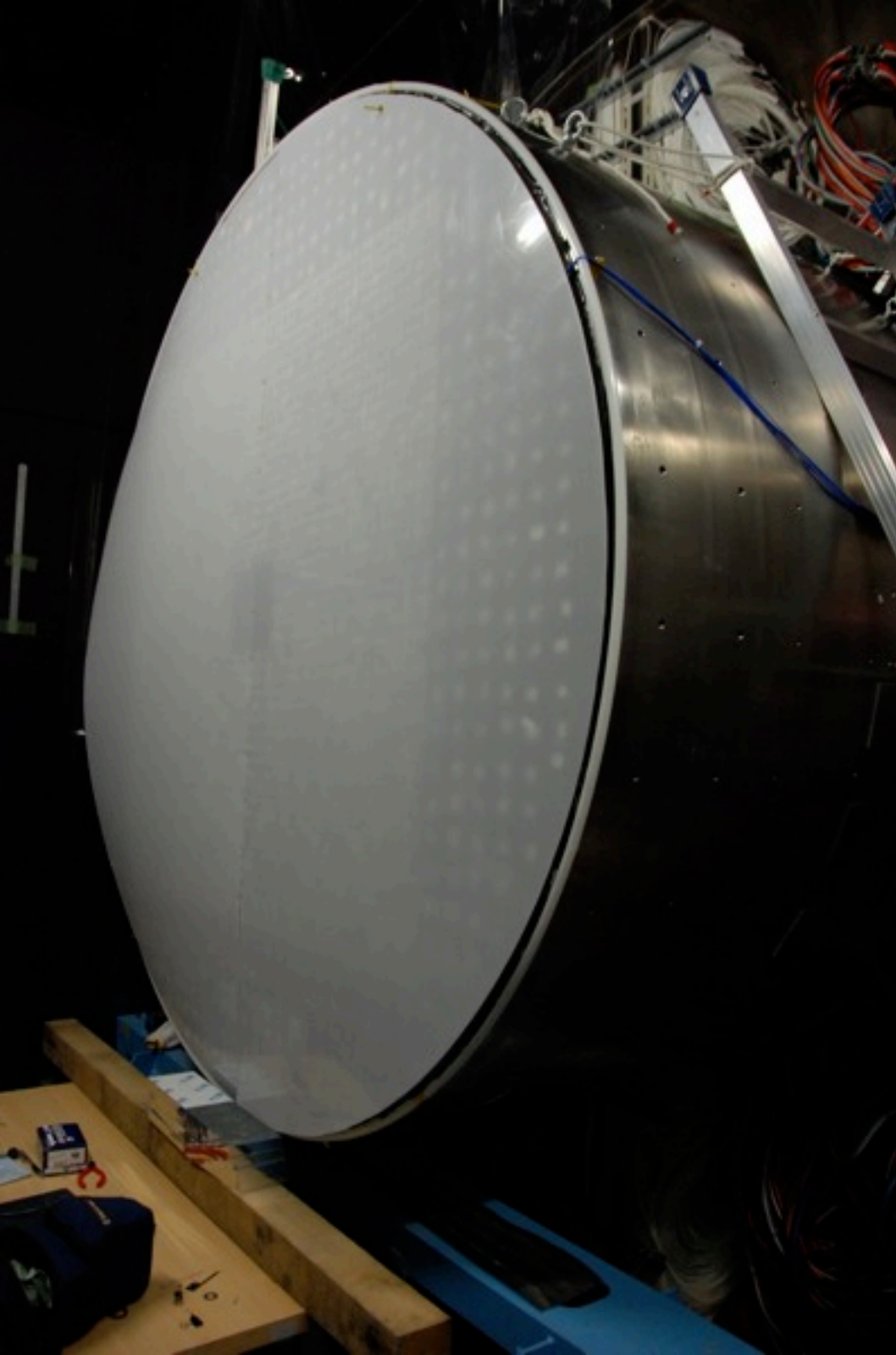




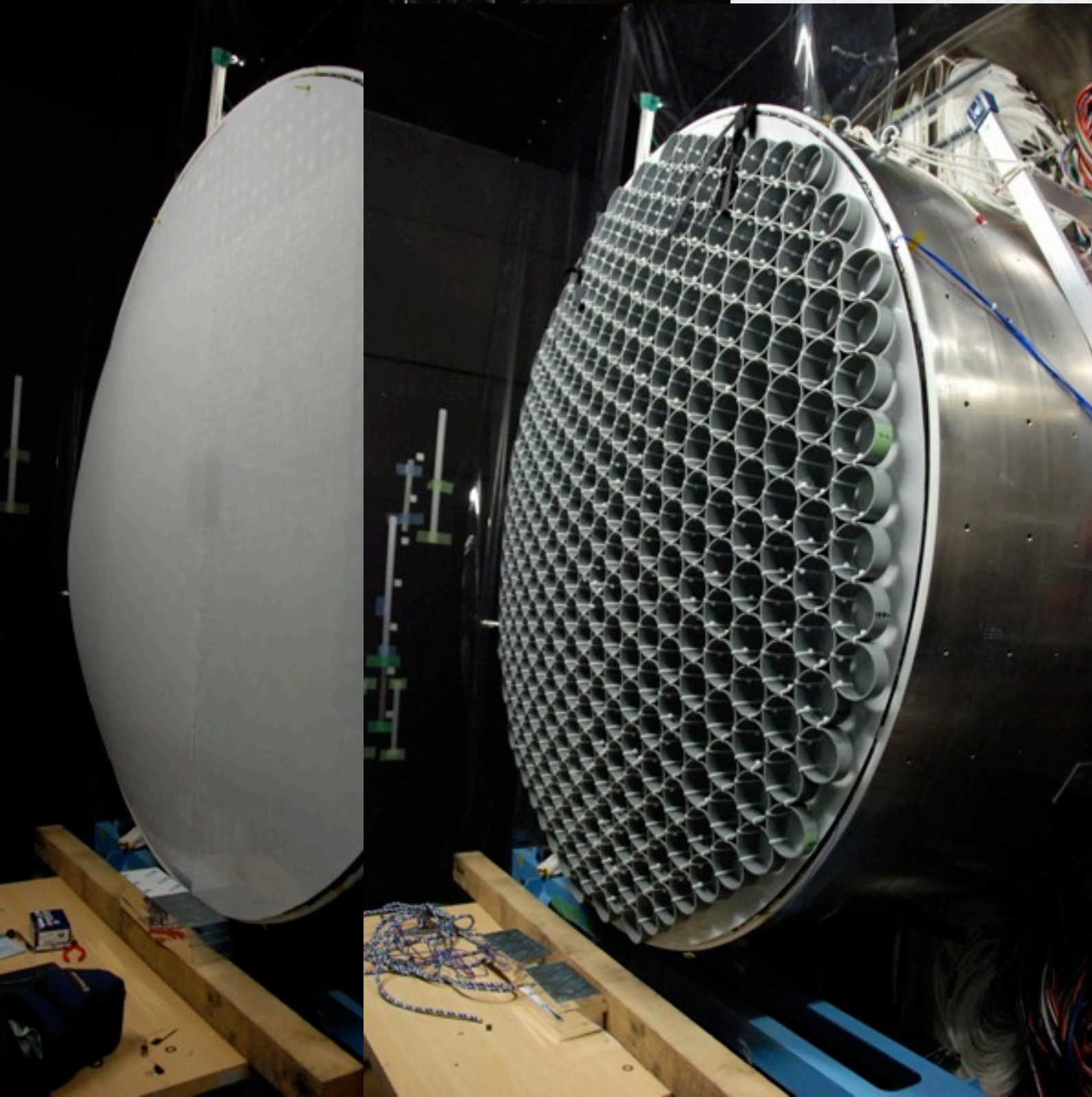




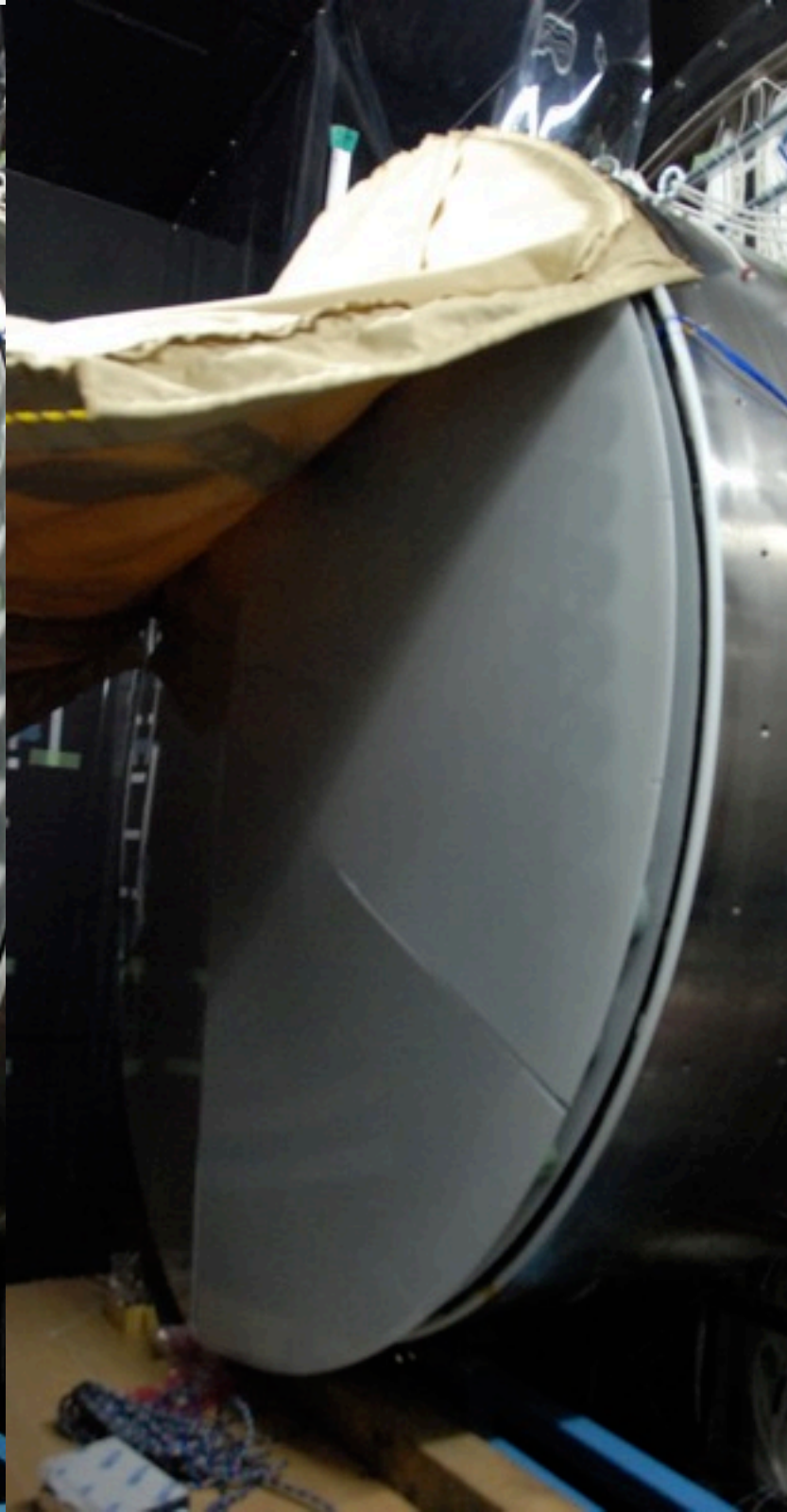
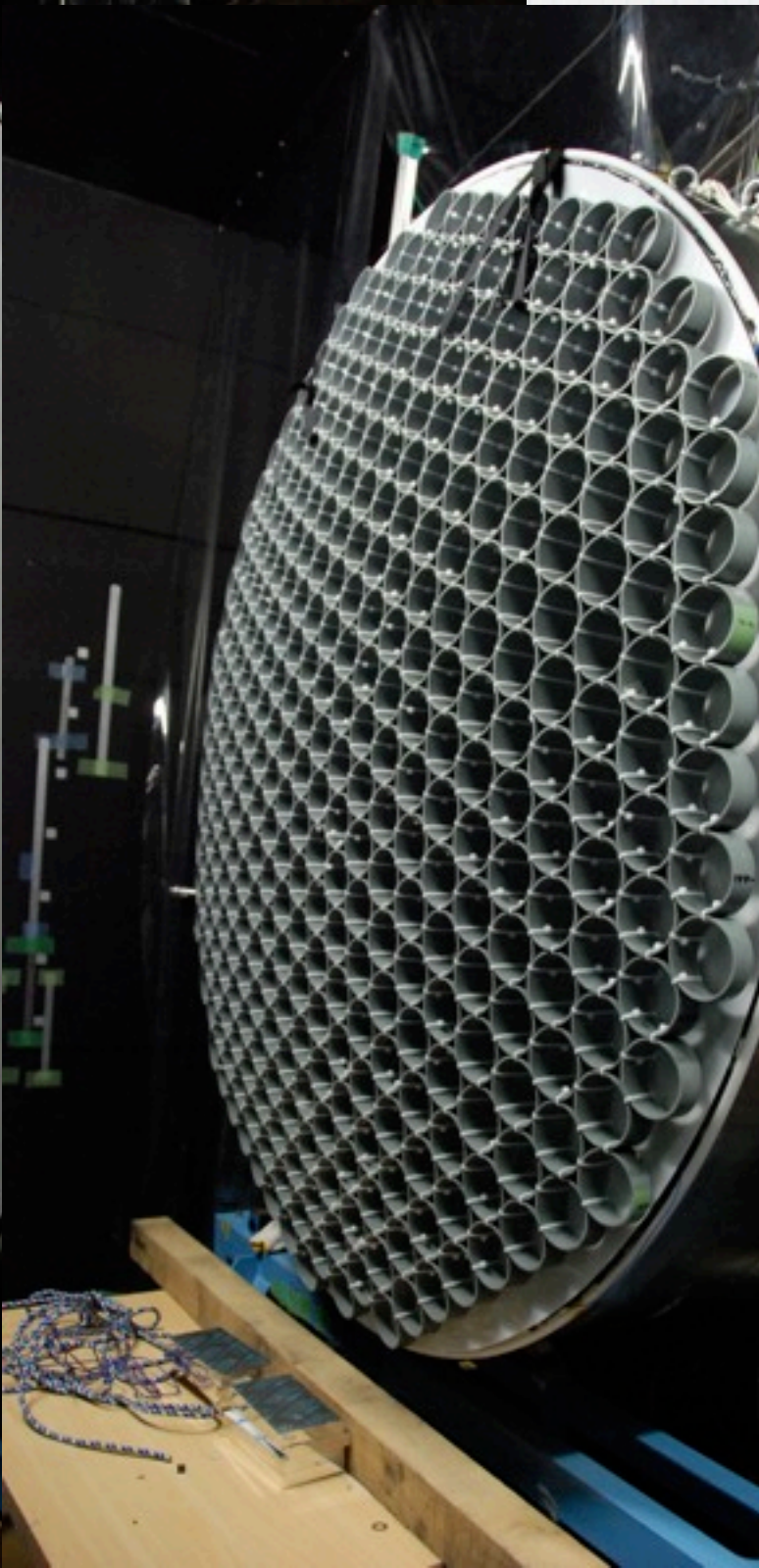
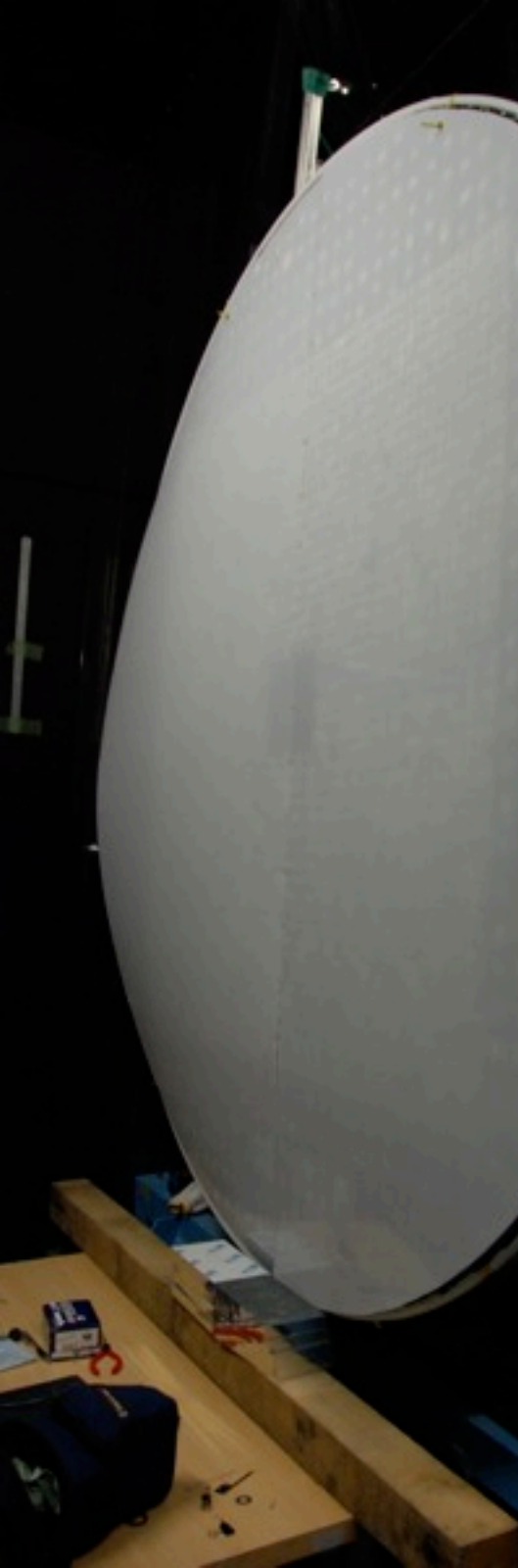






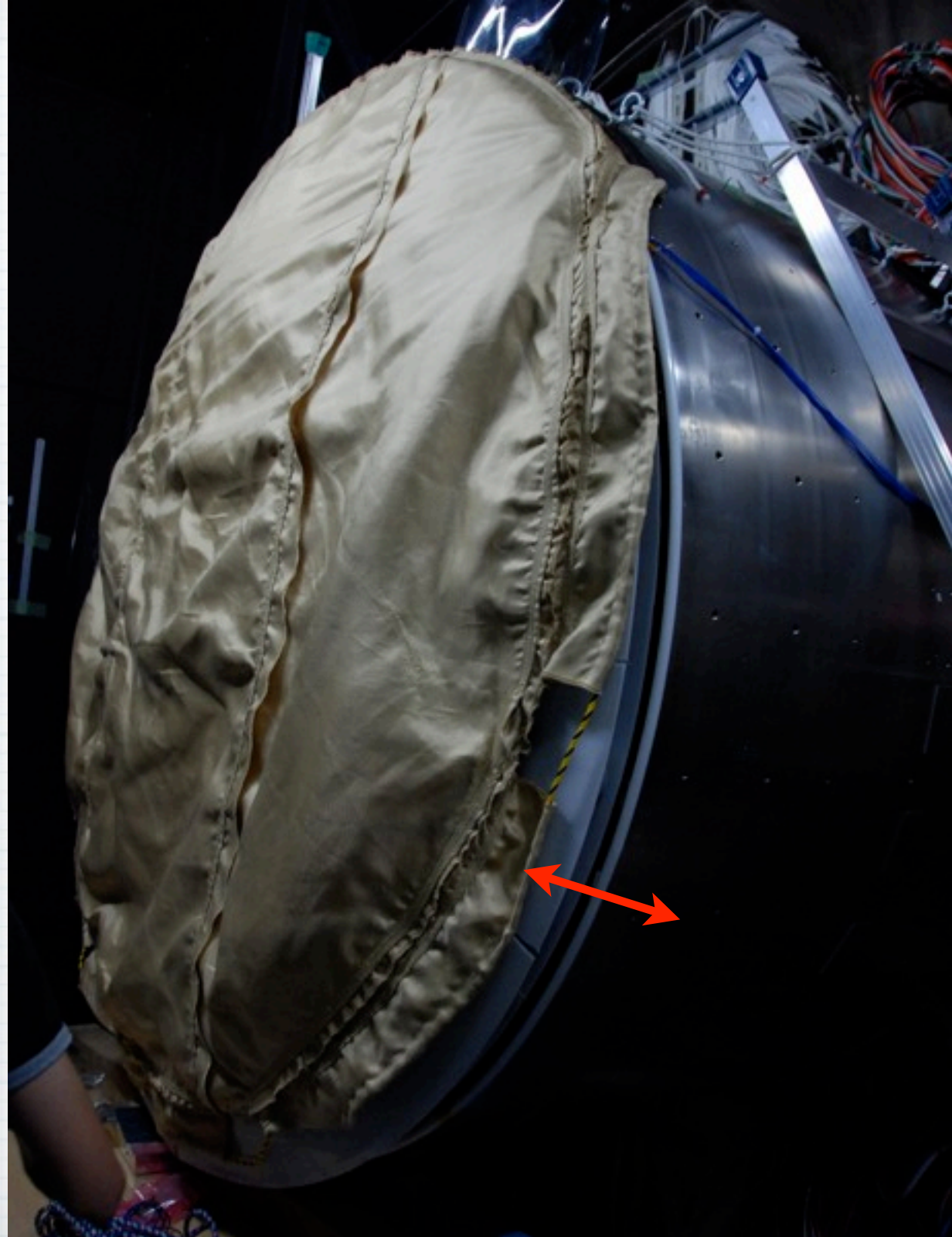








5cm short!





A photograph showing three people working on a large, light-colored fabric object, possibly a large bag or a piece of clothing, in a server room. The person on the left is wearing a white shirt and is using a pair of scissors to cut the fabric. The person in the middle is wearing a dark blue shirt and is also working on the fabric. The person on the right is wearing a grey shirt and glasses, and is looking down at the fabric. In the background, there are several server racks filled with equipment. A red-handled screwdriver is visible on the fabric in the foreground.

\* So we removed strings for half a circle, extended the side sheet by 7cm, and hand-sewed it.



Aug. 19, 2011 3AM  
= T - 6h



# What we learned

- \* Aramid cloths are strong
- \* They can be sewed together w/ 60% strength
- \* Prepare an length-adjustment mechanism for fabrics