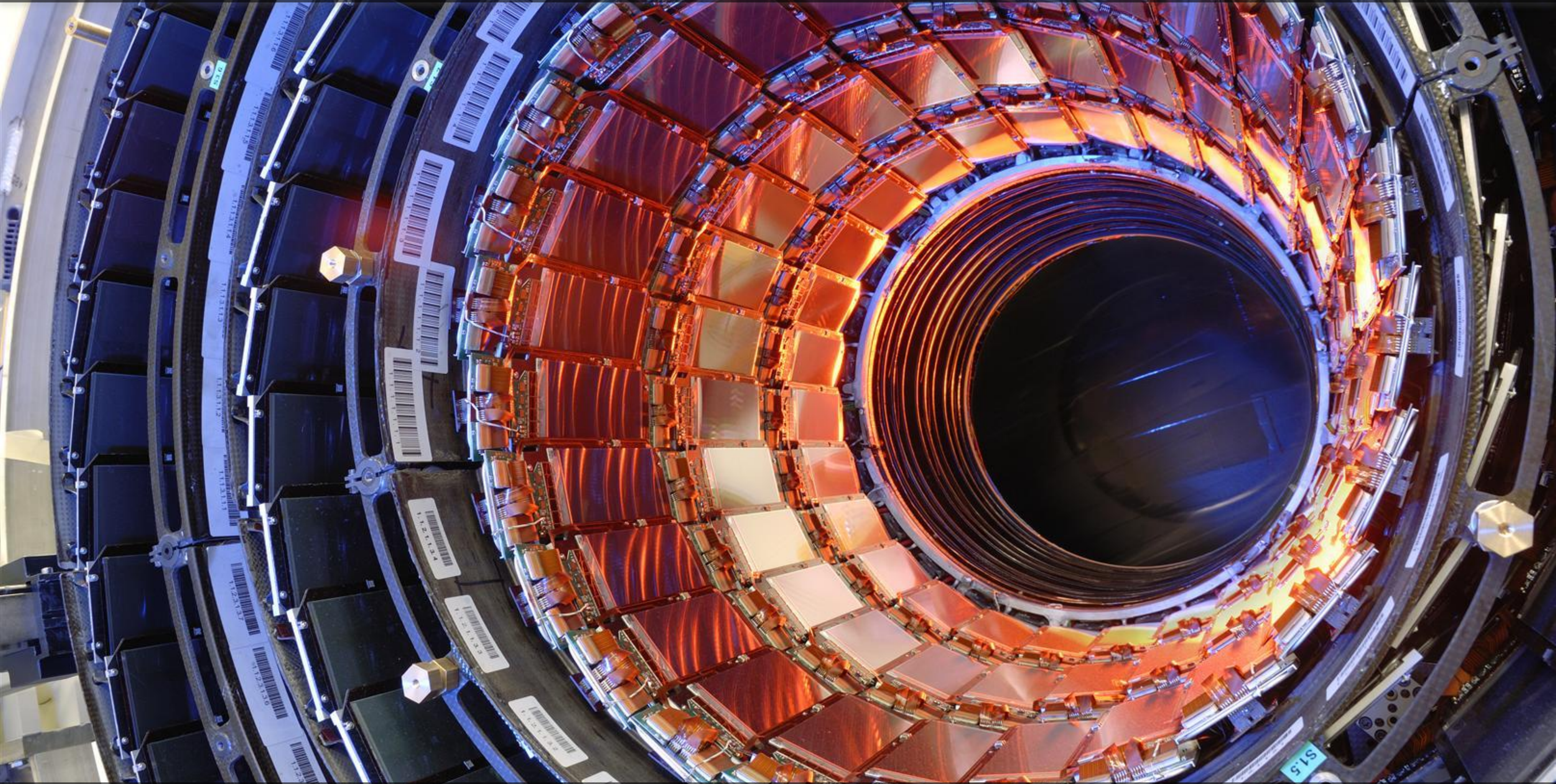
Needs of the CMS Strip Tracker

AIDA - Academia meets Industry Event



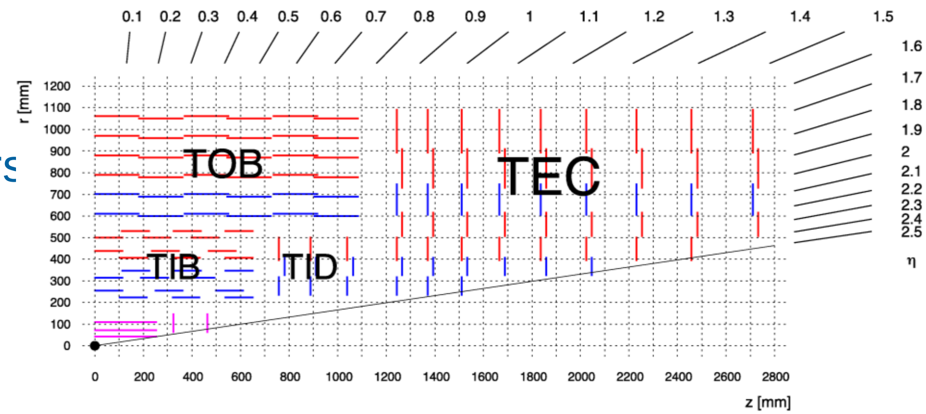
26 March 2012

Marko Dragicevic (HEPHY Vienna)

Current CMS Tracker

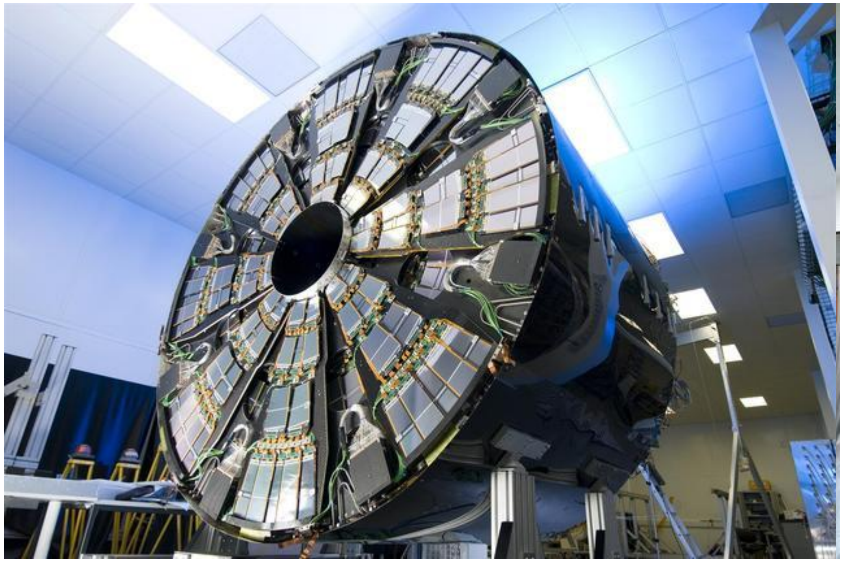
Tracker

- Barrel & Endcap geometry
- 200 m^2 of silicon
- 15.000 detector modules with 25.000 sensors
- Operating temperature < -10° C
- Expected fluence (10 years) 1×10^{14} 1 MeV Neutron/cm^2



Sensors

- 6” wafers, high resistivity FZ <100>
  - 500 µm thickness: 3.5–7.5 kΩcm
  - 320 µm thickness: 1.5–3.0 kΩcm
- p-on-n processing
- AC coupled strips
- PolySilicon resistor biasing
- Strip length ~10 cm
- 15 different sensor geometries ≈ 10x10 cm^2 (rectangular and wedge shaped)

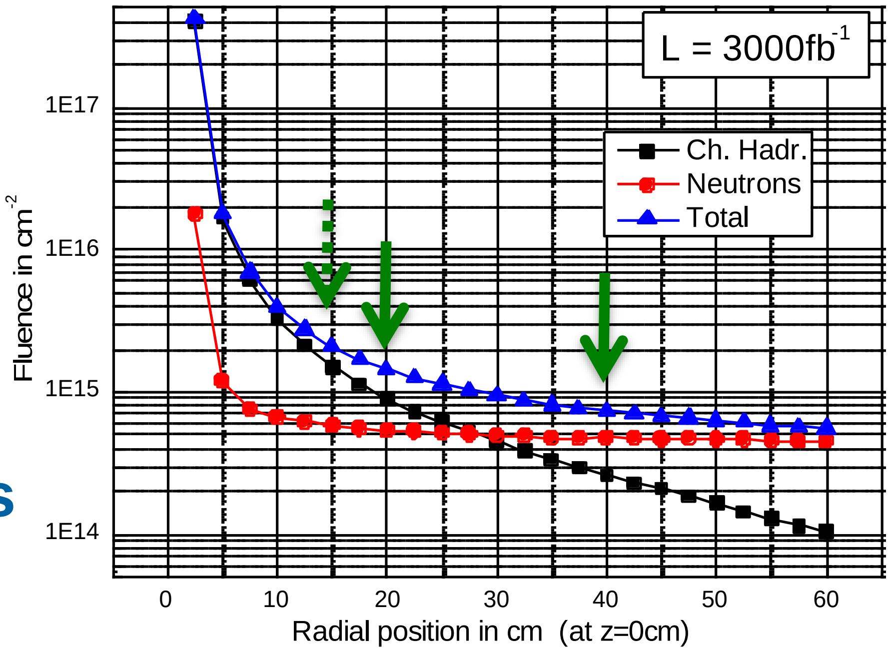


New CMS Tracker

- Performance of current tracker will have degraded significantly due to radiation damage by 2020
- Luminosity upgrade of the LHC
  - High-Luminosity-LHC = 5 x LHC
- Installation of the new tracker: **2020-2022**
- Two main challenges for the CMS Tracker
  - Even harsher radiation environment
  - Provide tracker information to the first level trigger

Challenges for the Upgrade: Radiation

- **Radiation dose** is about **5 – 10 times higher** than in current tracker
- Detector has to **survive 10 years** of operation
- Todays sensor technology might be sufficiently radiation tolerant for **outermost layers**
- For **intermediate to inner layers** we have a number of possible candidate materials/technologies
- *Innermost layers might even require something new?*

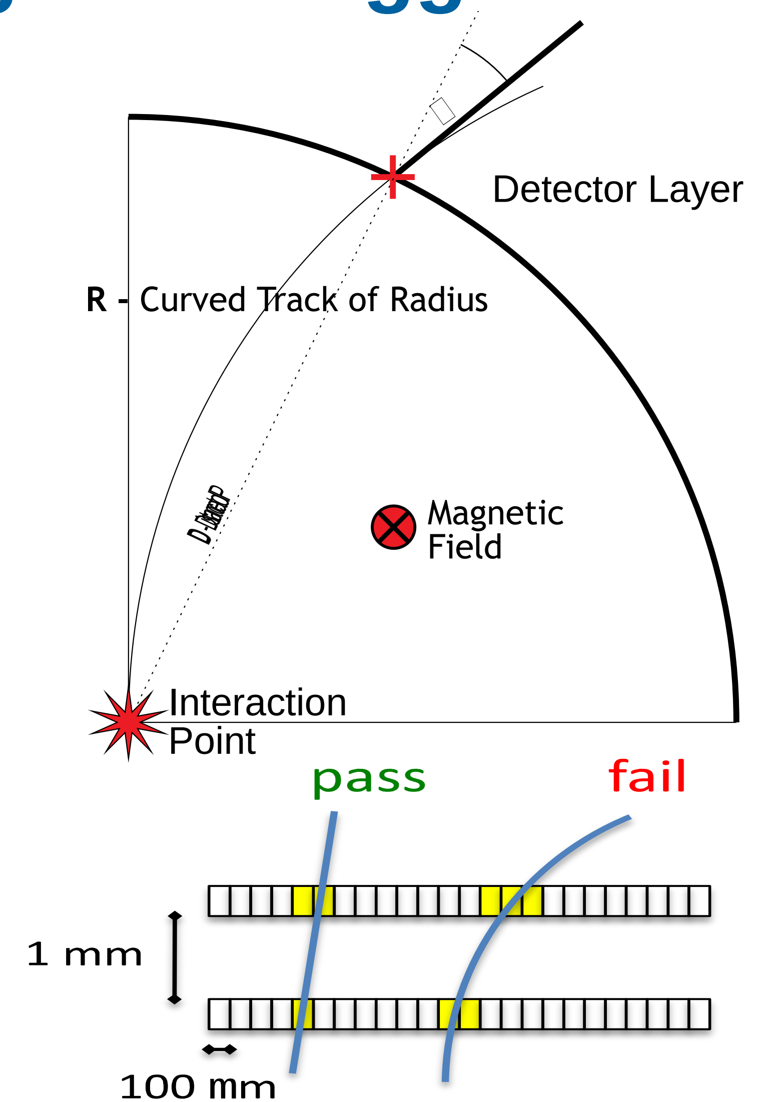


Expected fluence (10 years)

- Outermost layer (110 cm) ~ $1x10^{14}$ 1 MeV Neutrons/cm^2
- Innermost layer (20 cm) ~ $1x10^{15}$ 1 MeV Neutrons/cm^2

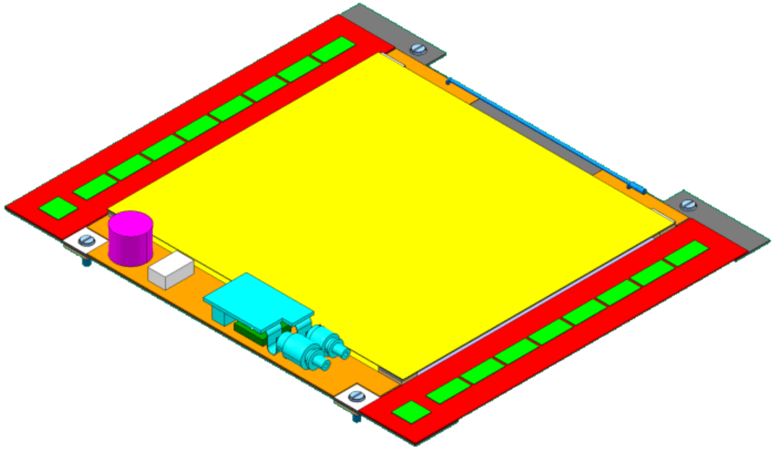
Challenges for the Upgrade: Trigger

- Cannot send full tracker information to the trigger due to bandwidth limitation
- Send hits from particles with high momentum to the trigger
- Estimate particle momentum on **module level**
  - At given magnetic field the track **curvature** depends on the **particle's p_t**
  - **Different curvature** results in **different incident angles** at a given radius
  - Estimate **incident angle** from **hit displacement** over a short distance
    → two parallel sensor planes

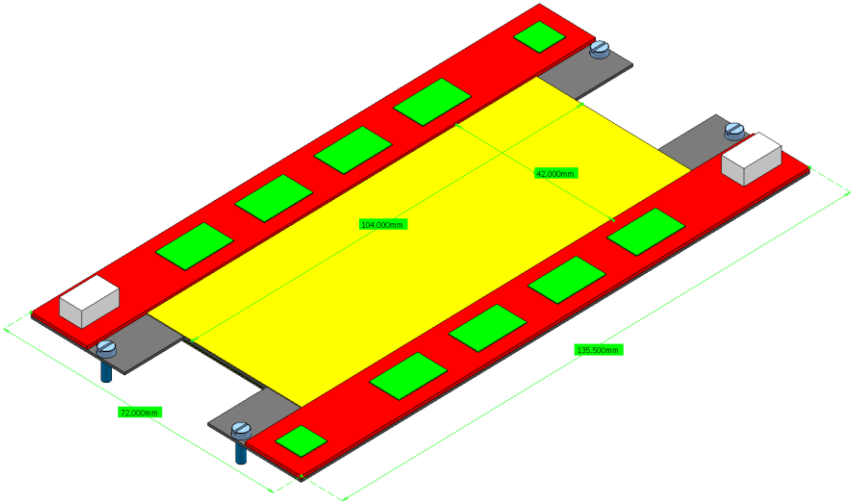


New Modules

- 2S: Module with two strip sensors
  - **2 x AC coupled strip** sensor with polysilicon biasing
  - 90 micron pitch
  - 10 x 10 cm size (6" wafers)
  - 2 x 1016 strips per sensor = 4064 Channels per module



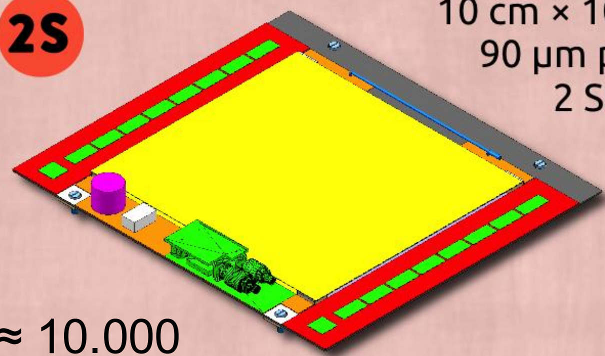
- PS: Module with one strip and one pixel sensor
  - **1 x AC coupled strip** sensors with polysilicon biasing
  - 100 micron pitch
  - **1 x DC coupled macro-pixel** sensors with polysilicon or punch trough biasing
  - long pixels/short strips ~ 1-2 mm length
  - 10 x 4 cm size (6" wafers)
  - 32.768 pixels + 2032 strips



Barrel + End-cap layout

From S. Mersi, 30.January 2012

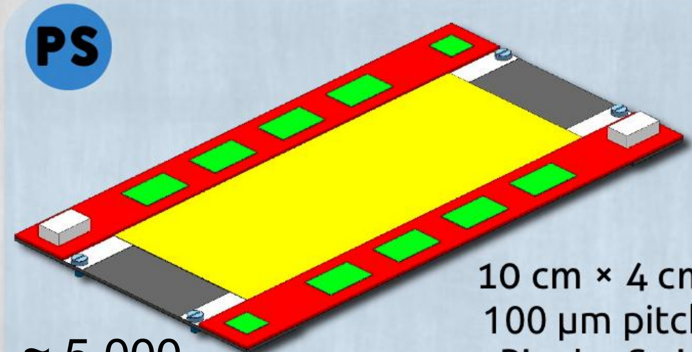
2S



10 cm × 10 cm
90 µm pitch
2 Strips

≈ 10.000

PS



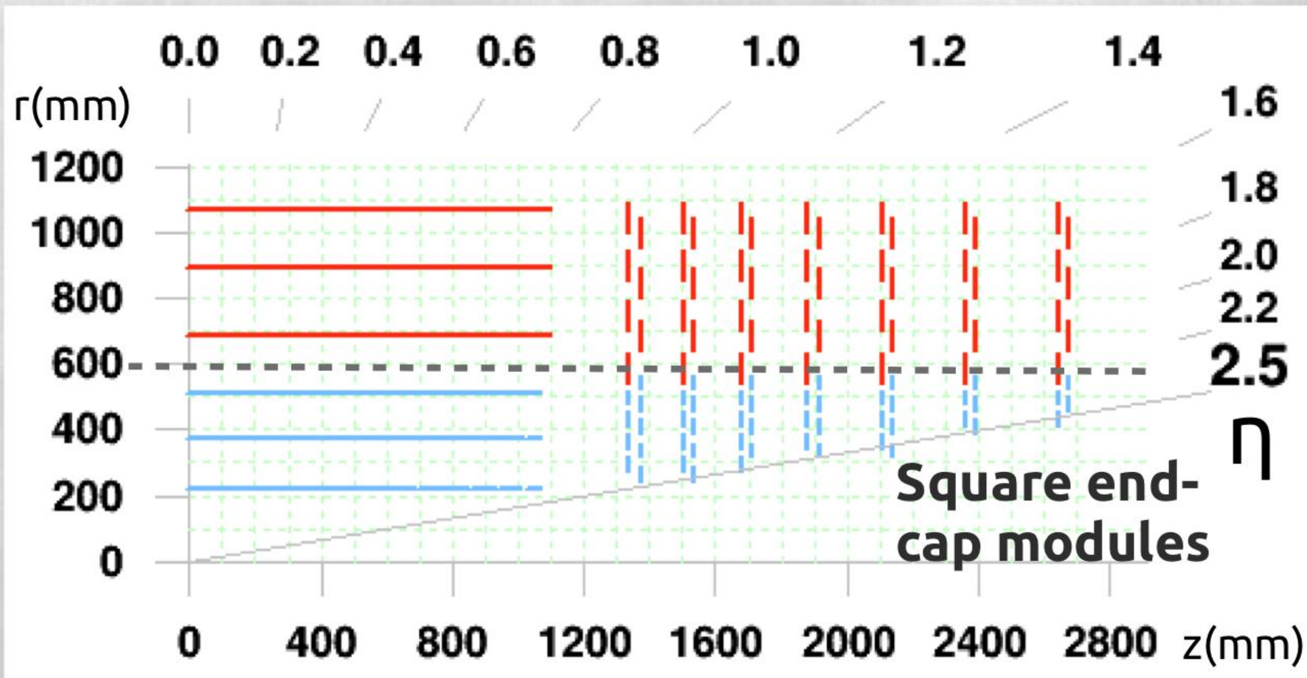
10 cm × 4 cm
100 µm pitch
Pixel + Strip

≈ 5.000

→ ≈ 240 m² of silicon

Lower density
2S modules
outside

z info in trigger
θ info in trigger
PS modules inside
2 for measurement
+1 for redundancy

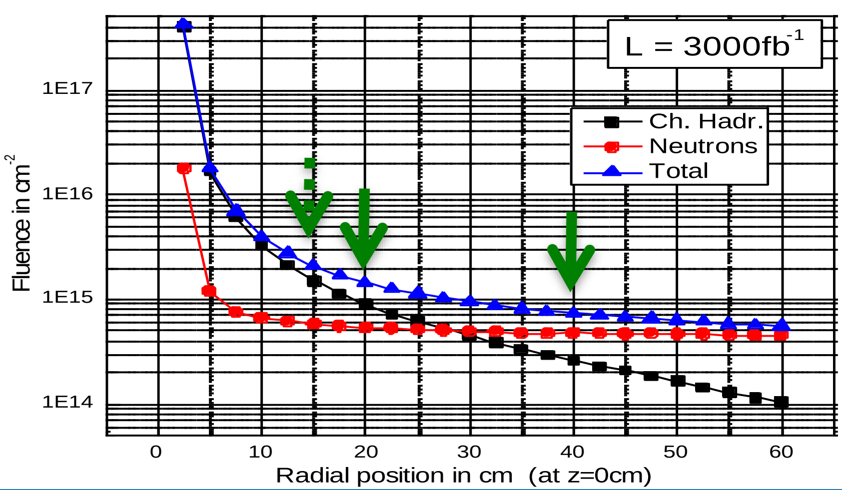


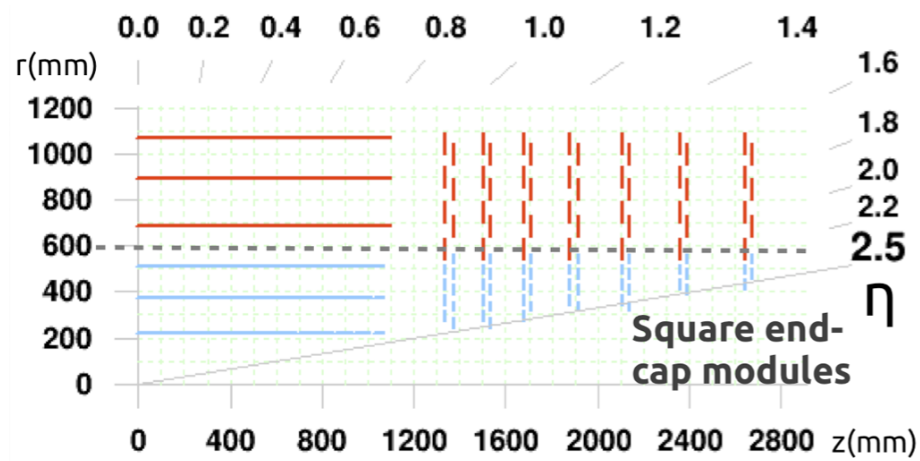
NEW SENSORS

Sensors: Bulk Materials

- Different radiation tolerant bulk materials are potential candidates
- We might use one or several materials optimised to different radii from the interaction point
  - Radiation higher towards center
  - Sensor area increases towards outside

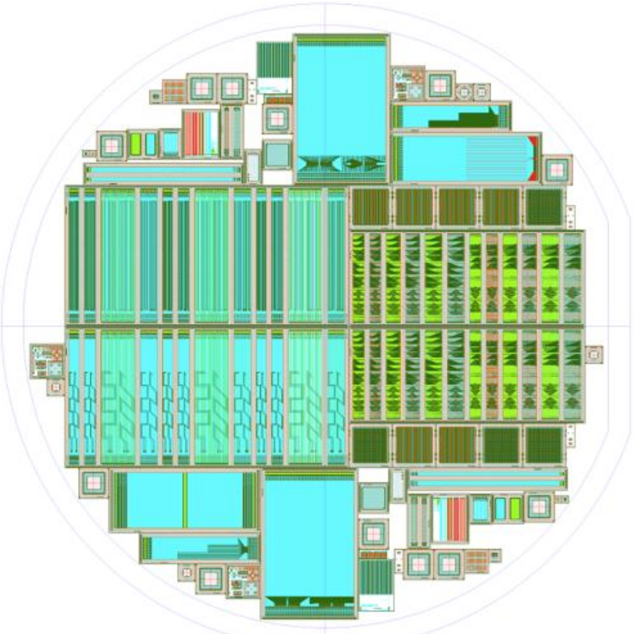
→ Cheaper „standard“ materials in outer reagion, more radiation tolerant materials inside





Sensors: Bulk Materials

- CMS Tracker has a large campaign on-going investigating radiation tolerant materials and production processes using test sensors and structures



	physical thickness		deep diffusion		carrier wafer		
active thickness	320µ	200µ	200µ	120µ	120µ	100µ	50µ
FZ	X	X	X	X	X		
MCz		X					
Epi						X	X

Sensors: Processing

We investigate 3 processes (on all materials):

- **p-on-n:** p-strips in n-bulk
- **n-on-p, p-stop:** n-strips in p-bulk with p-stop isolation
- **n-on-p, p-spray:** n-strips in p-bulk with p-spray isolation

We will need:

- **AC coupled strip** sensors (single-sided) with polysilicon biasing
- **DC coupled macro-pixel** sensors with polysilicon or punch through biasing

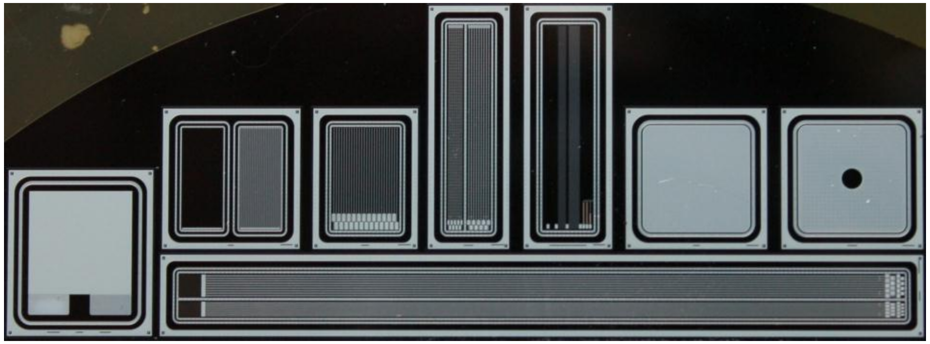
Sensors: Important Characteristics

- HV operation
  - Long-term stable operation up to 500 V
  - Even after irradiation!
- Low reverse bias current
  - < 1 µA@400V@20° C (~ < 1 µA/cm^3) for 10 x10 cm^2 area, 320 µm thickness
- High quality dielectric between aluminium readout strip – strip implant
  - Low count of pinholes (short between alu - implant) < ‰ of strips
  - Breakthrough voltage of dielectric > 150 V
- Stable production line
  - Changes in the production might influence the required quality and radiation hardness
  - Even small changes can have unexpected effects

Sensors: Electrical Characterisation

Measurements on dedicated test structures
to assess the quality of production process

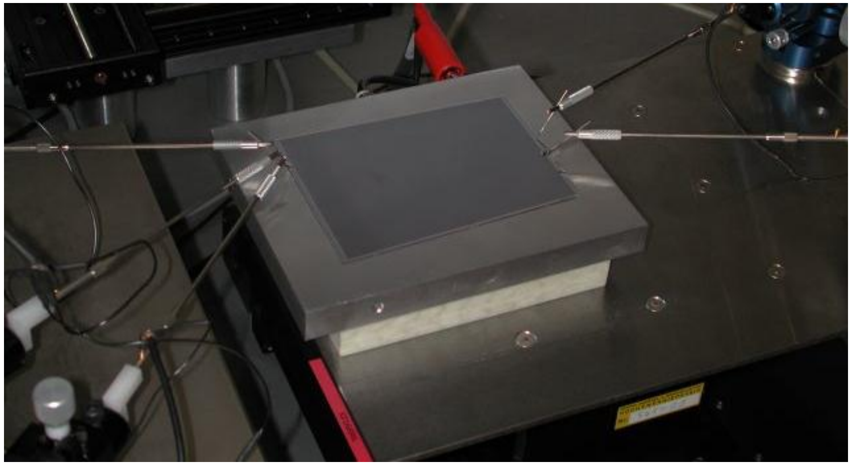
- Diode Properties
  - Full depletion voltage (V_{depl} from CV-curve)
  - Reverse bias current (I_{leak} from IV-curve)
- Strip Properties
  - Interstrip resistance: R_{int}
  - Interstrip capacitane: C_{int}
- Oxide Properties (dielectric between strip implant and readout strip)
  - Coupling capacitance (oxide thickness): C_{ox}
  - Dielectric current, breakthrough voltage: I_{diel}, V_{break}
  - Flatband voltage (MOS, GCD): V_{fb}
  - Surface current (GCD): I_{surf}
- Sheet Resistances
  - Polysilicon: R_{poly}
  - Implants: R_{strip}, R_{stop}
  - Alu: R_{alu}



Sensors: Electrical Characterisation

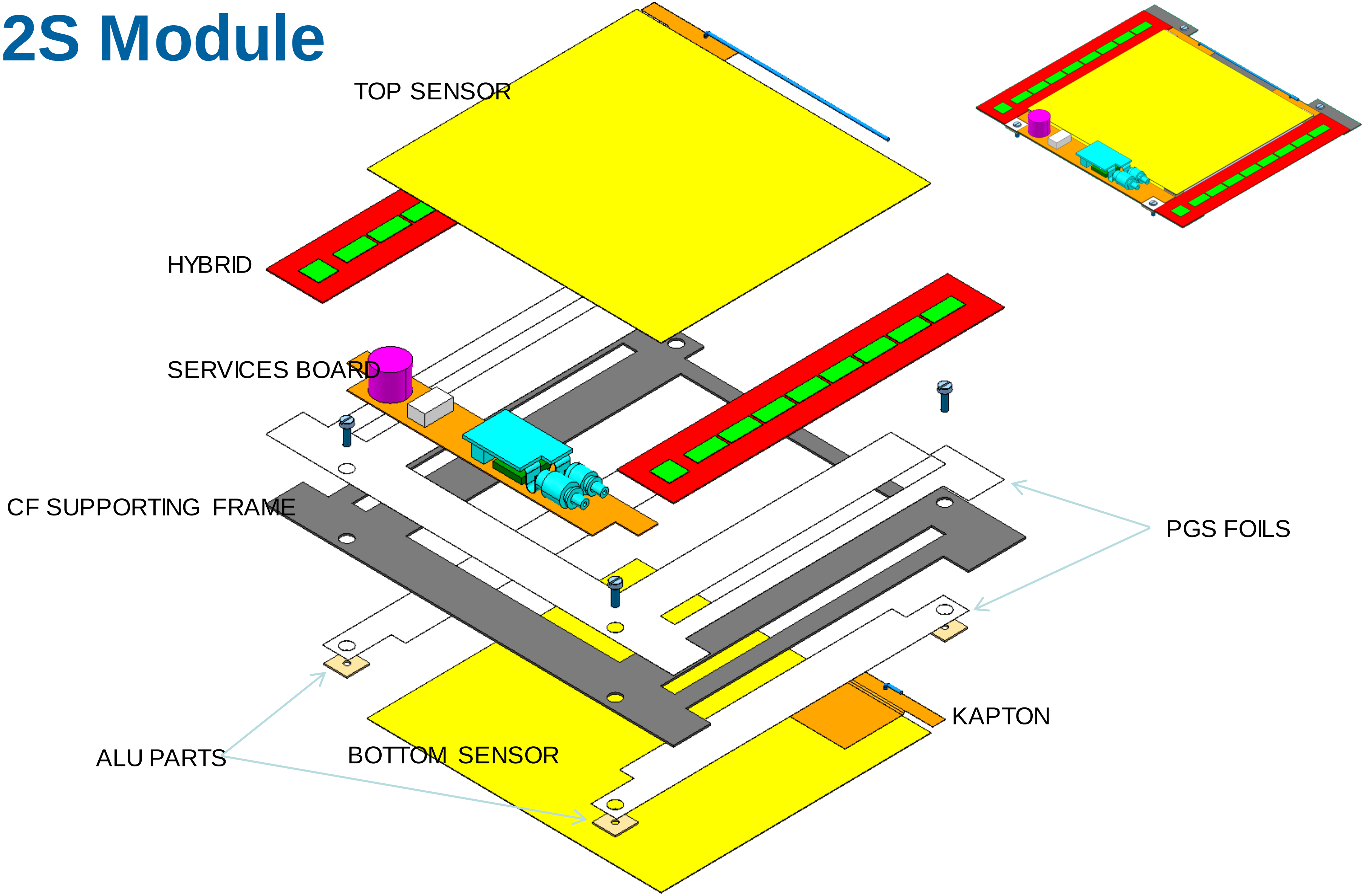
Measurements on sensor
to assess the quality of sensors on a sample basis

- Global Measurements
  - Full depletion voltage (V_{depl} from CV-curve)
  - Reverse bias current (I_{leak} from IV-curve)
- Strip Properties
  - Interstrip resistance: R_{int}
  - Interstrip capacitane: C_{int}
  - Coupling capacitance: C_{ox}
  - Polysilicon resistor: R_{poly}
  - Pinholes (current through dielectric)

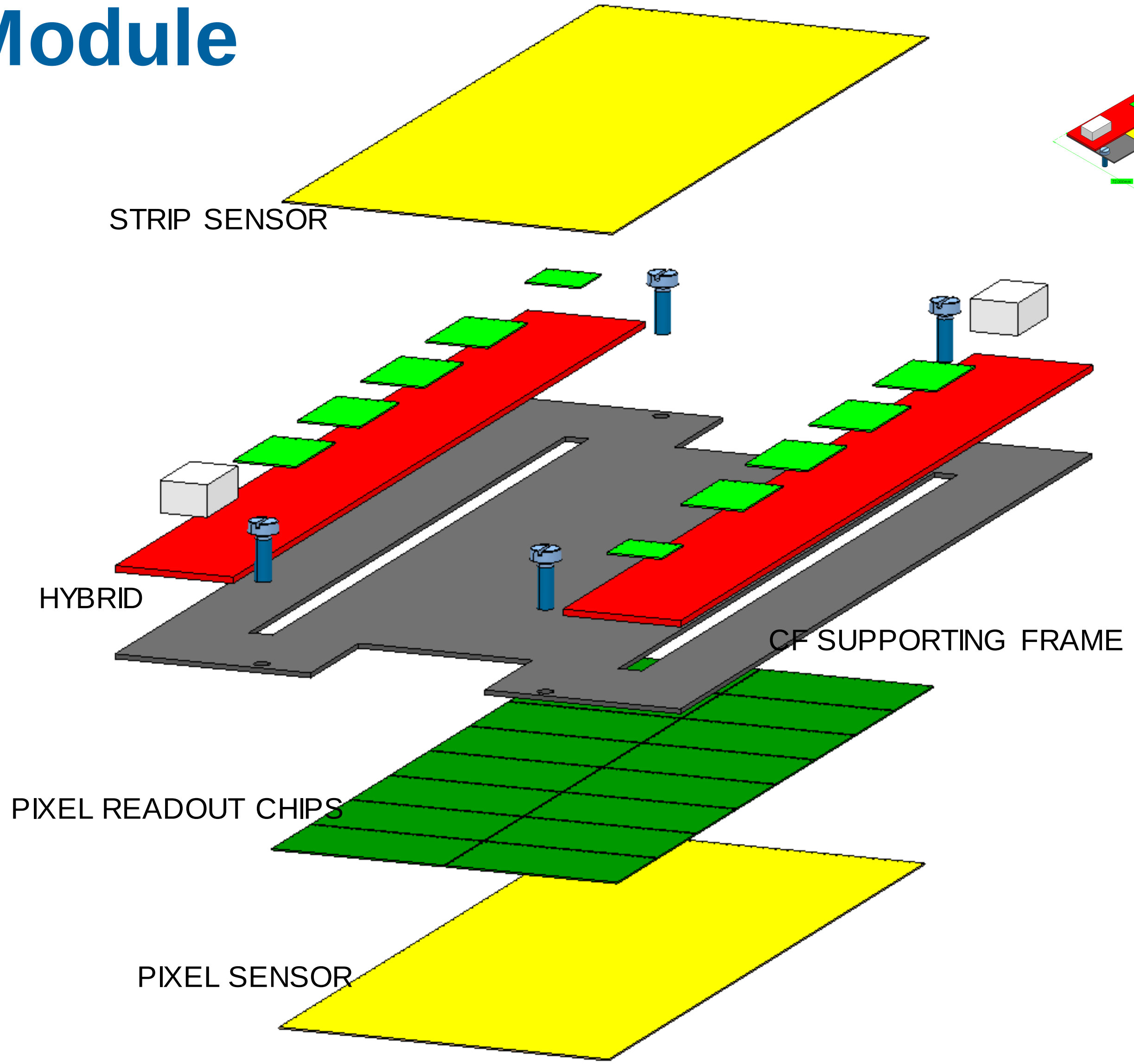


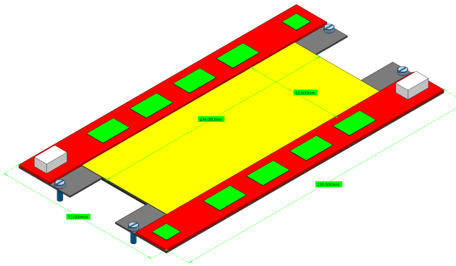
MODULE COMPONENTS

2S Module


TOP SENSOR
HYBRID
SERVICES BOARD
CF SUPPORTING FRAME
PGS FOILS
KAPTON
ALU PARTS
BOTTOM SENSOR

PS Module


STRIP SENSOR
HYBRID
CF SUPPORTING FRAME
PIXEL READOUT CHIPS
PIXEL SENSOR



2S Modules: Electronics

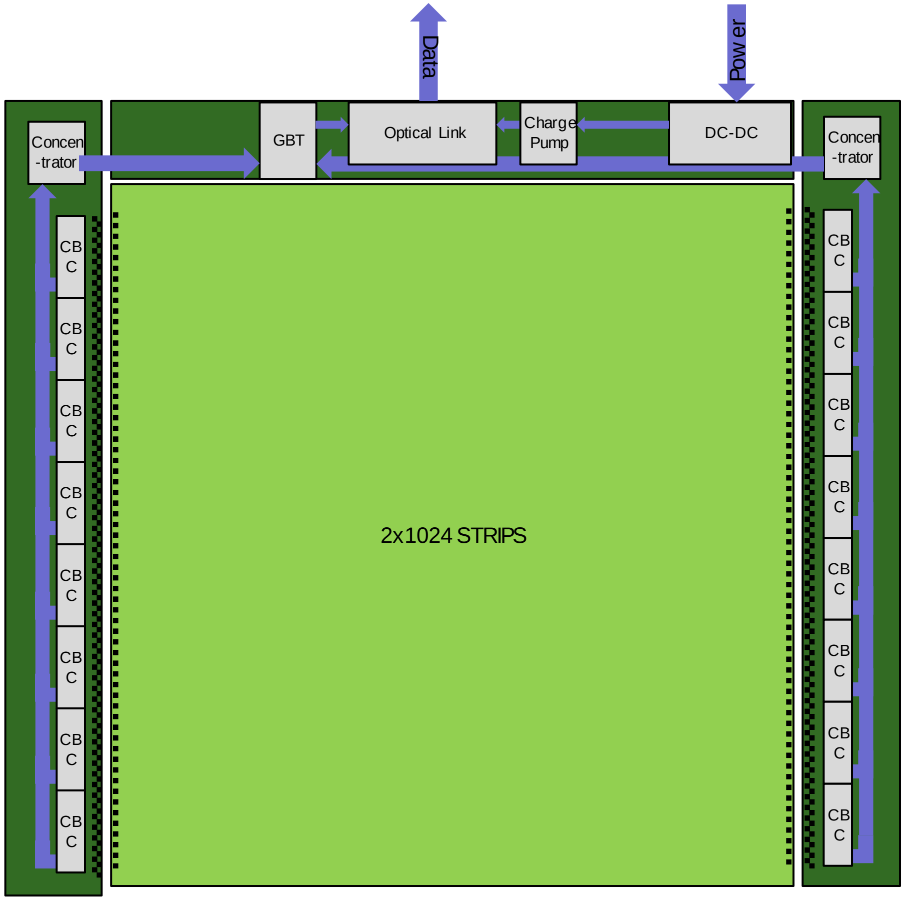
Hybrid

- 2 x 8 readout chips with 254 channels each
- Chips are bump bonded to hybrid
- Communicate with neighbour chip and concentrator chip
- Each chip connects to strips on top and bottom sensor via wire bonding from hybrid

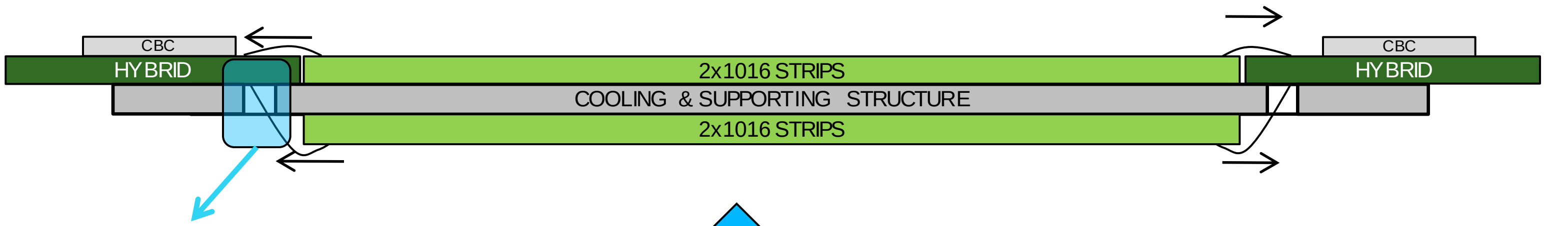
→ Lightweight hybrid board needs multiple layers with high density interconnects and bump and wire bonding capability

Service board

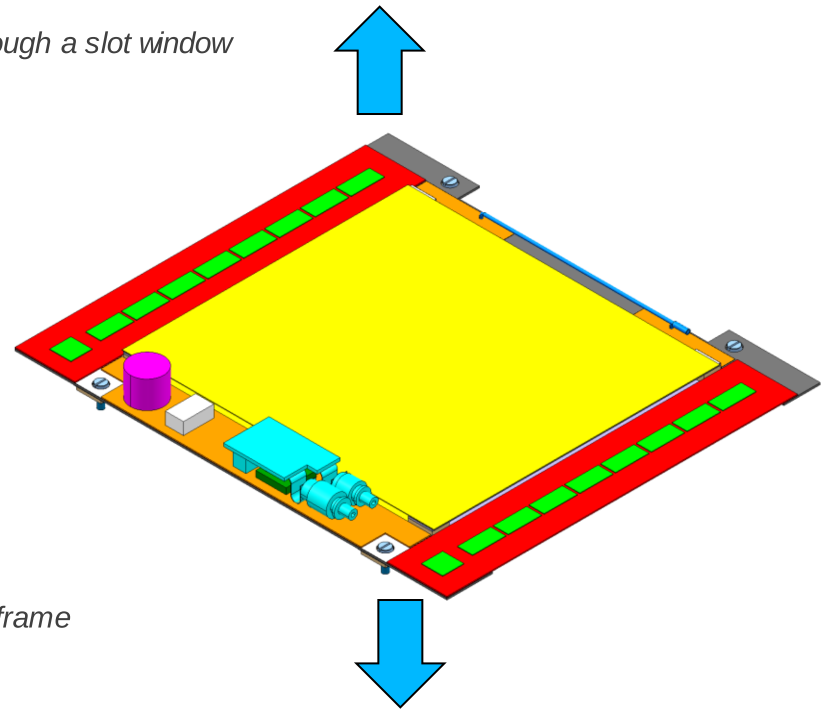
- Might be an additional board or integrated with hybrid
- Houses DC-DC converter, optical link and the corresponding connectors
- Lightweight connectors for low voltage, high voltage and optical data link



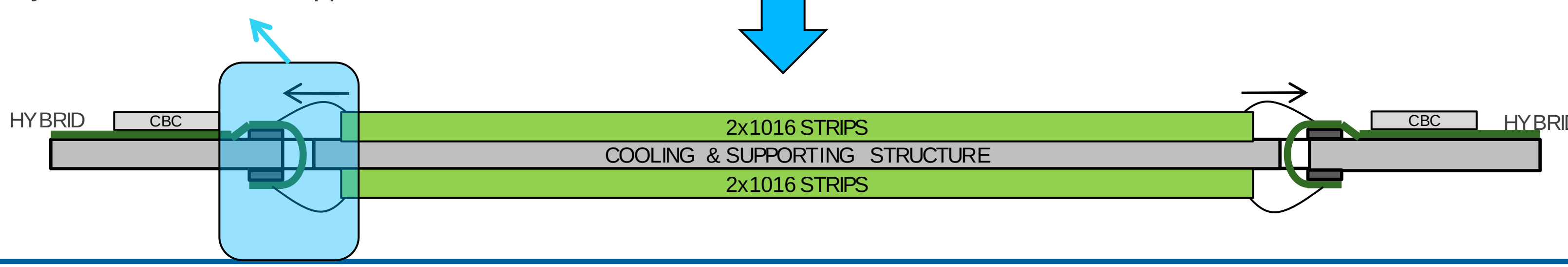
2S Modules: Chip to Sensor Connections



Bottom layer wirebonded through a slot window in the carbon fiber frame.

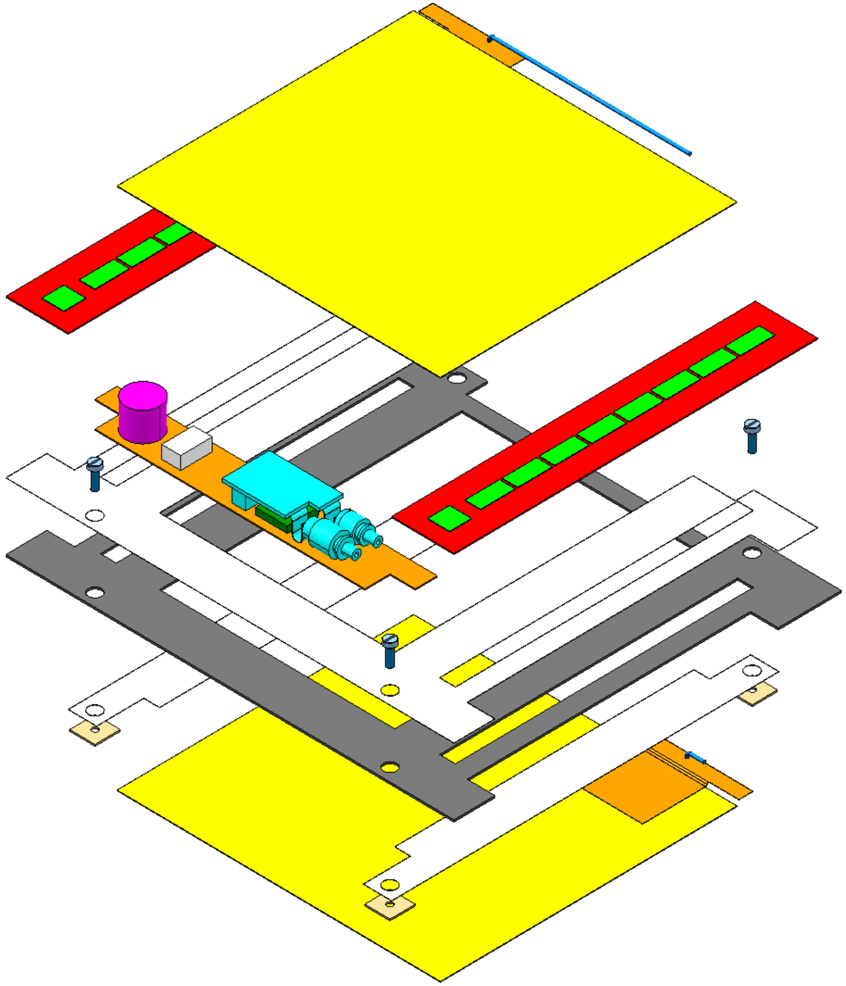


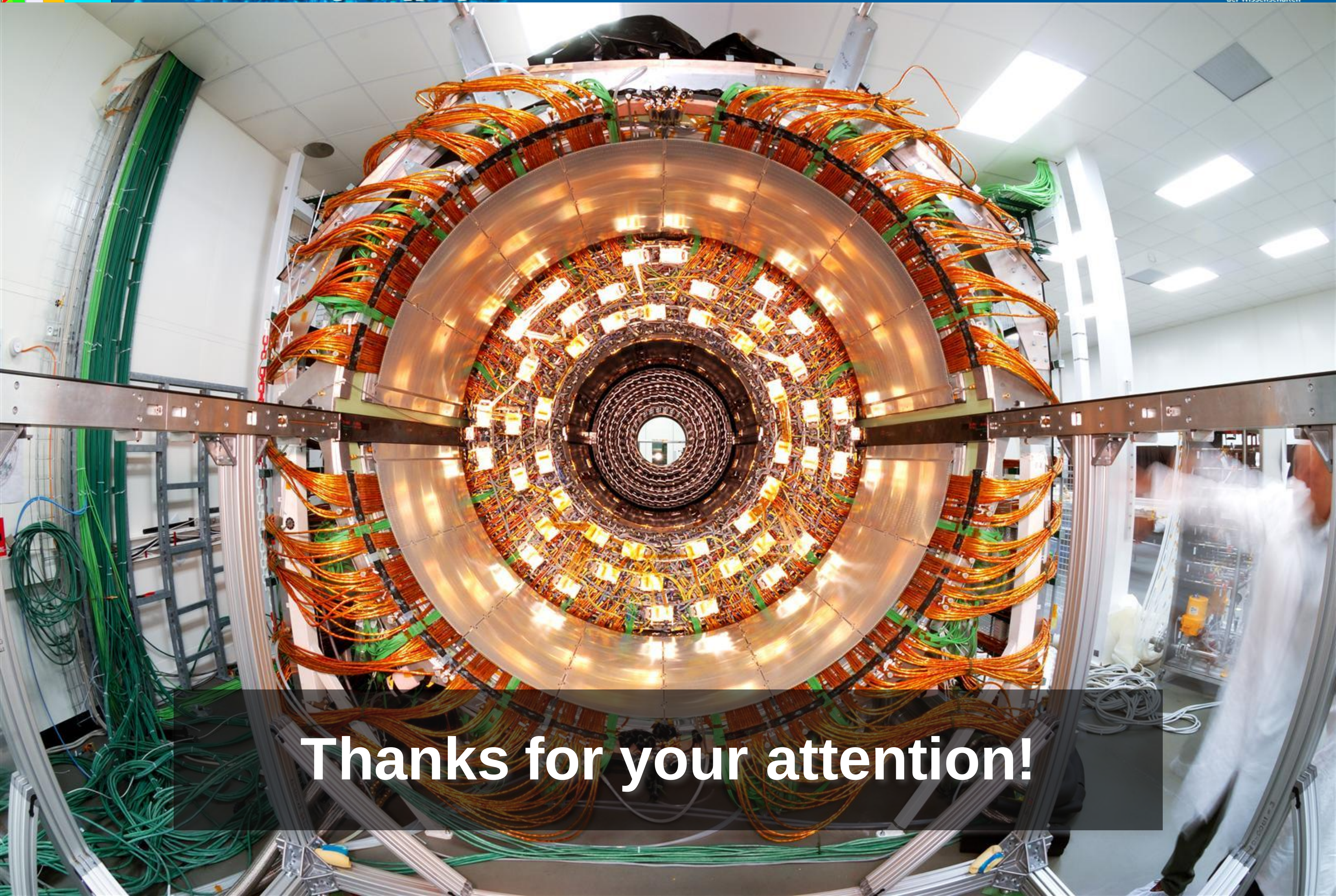
Flexible Hybrid folded around support frame



2S Modules: Support and Cooling

- Stiff and lightweight support materials (CFRP)
- Thin heat spreader material for thermal management
- Radiation tolerant glue with good thermal conductivity





Thanks for your attention!