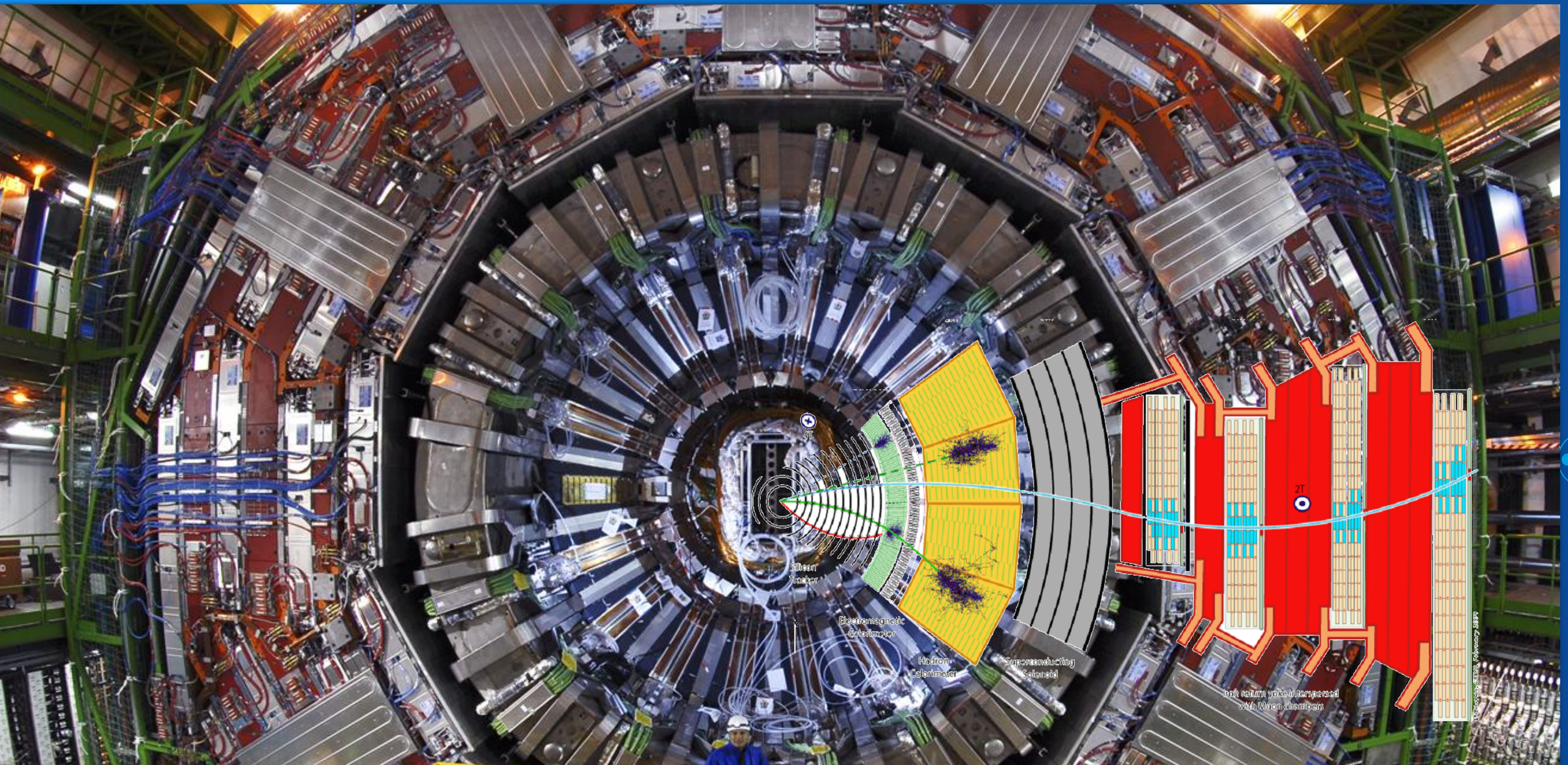
CMS Outer Tracker Activities

Doris Eckstein

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

CMS Detector

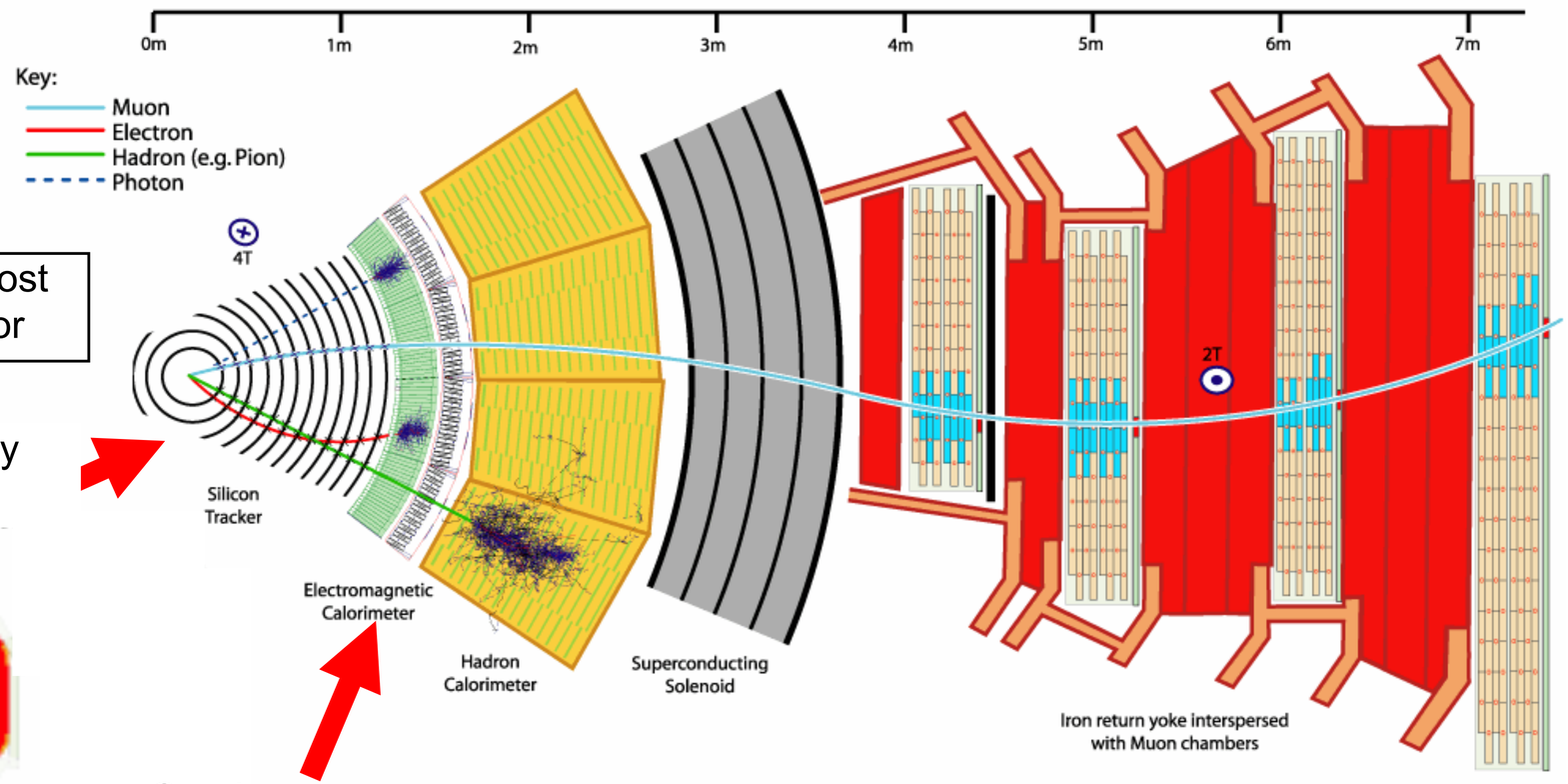


CMS Detector

Tracker: Precise measurement of track and momentum of charged particles due to magnetic field.

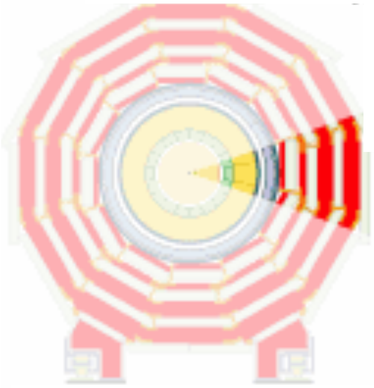
Calorimeter: Energy measurement of photons, electronics and hadrons through total absorption

Muon-Detectors: Identification and precise momentum measurement of muons outside of the magnet



Vertex: Innermost tracking detector

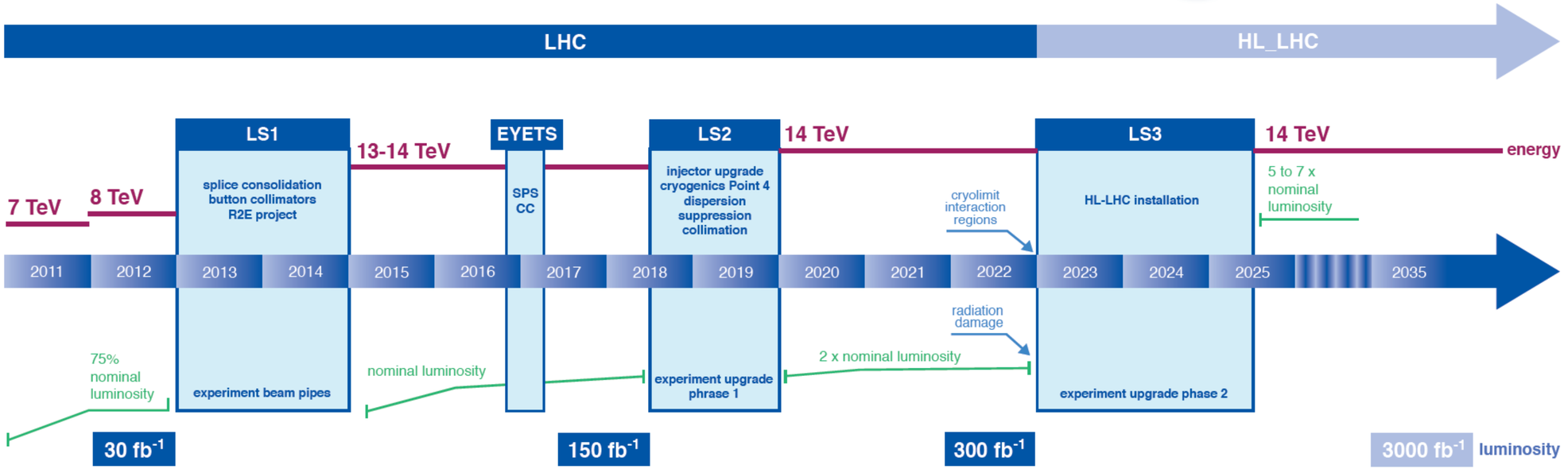
High granularity for the tracker



Good energy resolution up to highest energies

LHC Schedule - Upgrade

LHC / HL-LHC Plan



During LS3: upgrade of accelerator to peak luminosities of 5×10^{34} cm^{-2}s^{-1} (ultimately up to 7.5×10^{34} cm^{-2}s^{-1})

—> collect up to 300 fb^{-1} per year (450 fb^{-1} ultimately)

—> irradiation levels 1.1 x 10^{15} n_{eq} x cm^{-2}

—> requires new trigger concepts

—> requires higher granularity

CMS Tracker will be upgraded

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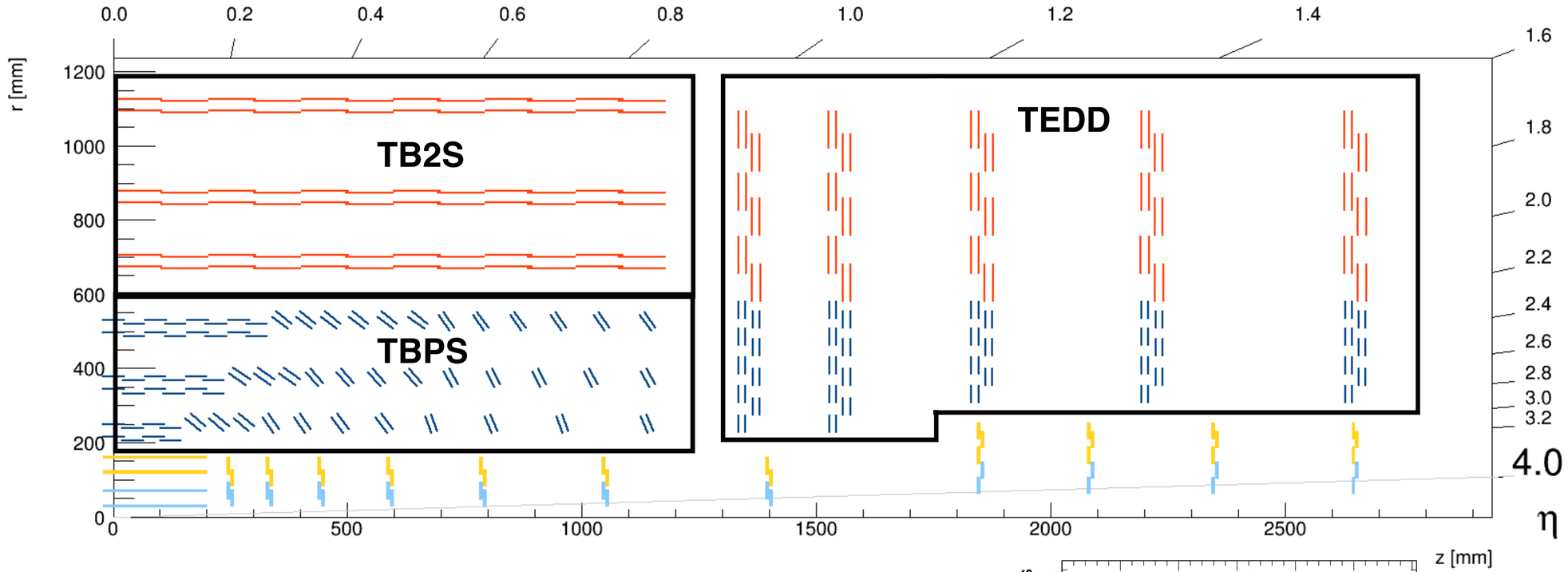
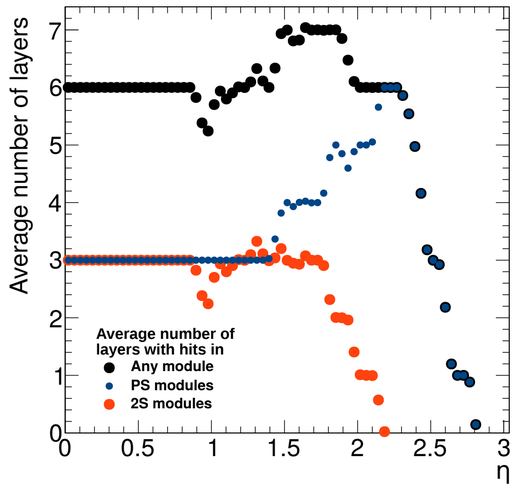
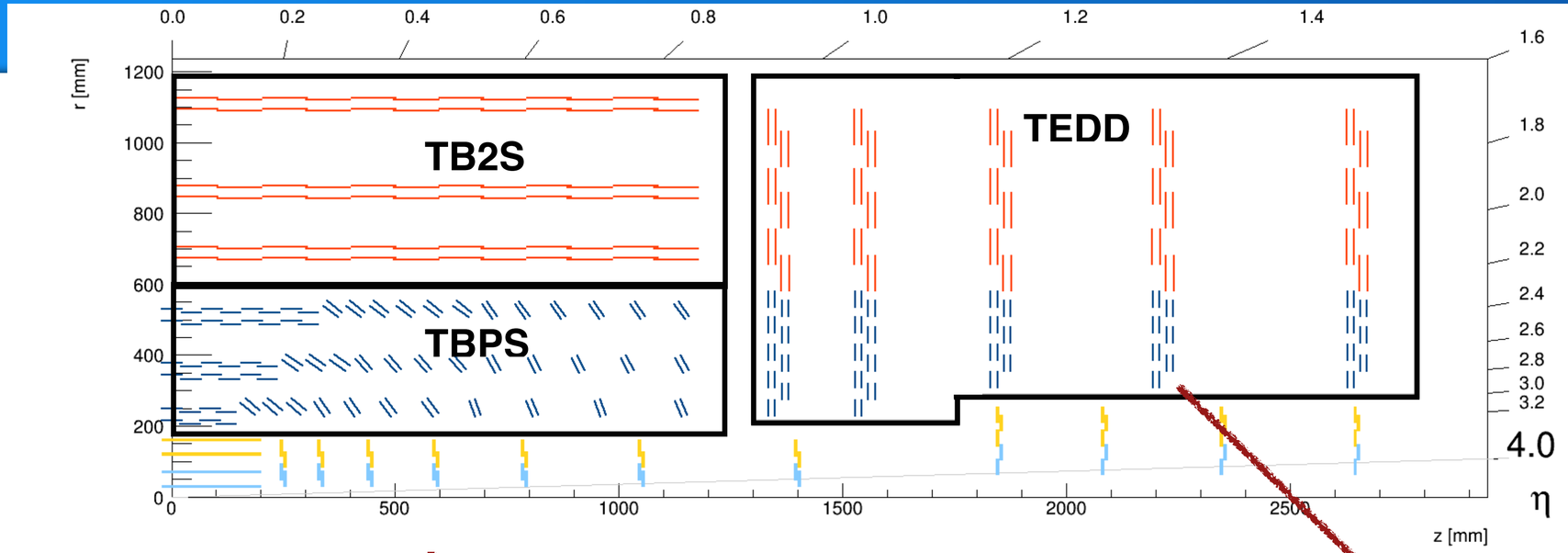
CMS Tracker Concept

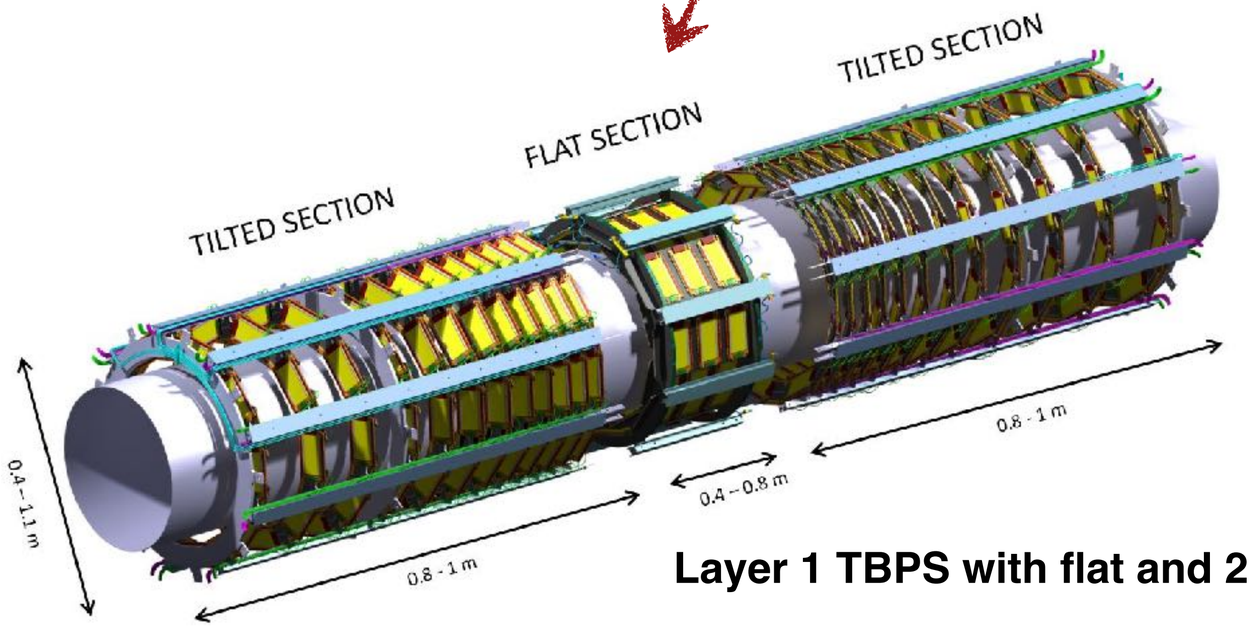


- Layout with barrel (6 layers) and endcaps (5 double discs)
- Modules arranged to reach hermeticity
  - TBPS: barrel with straight and tilted section of PS modules
  - TB2S: barrel with 2S modules
  - TEDD: endcap with PS modules in inner and 2S in outer region
- Only 3 types of rectangular sensors throughout tracker



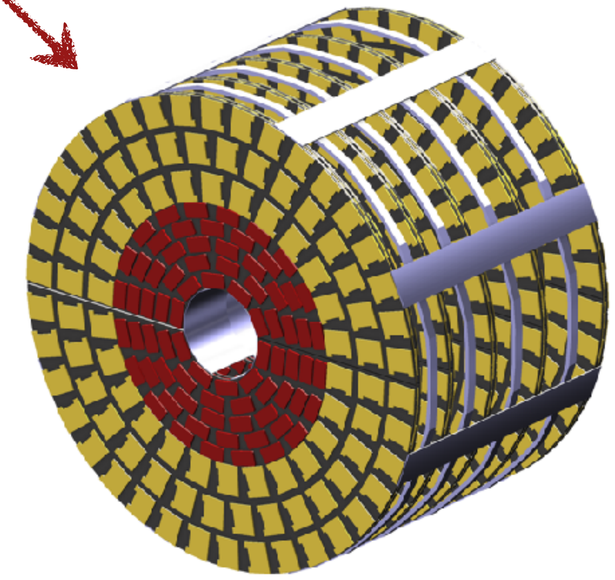
CMS Tracker Concept



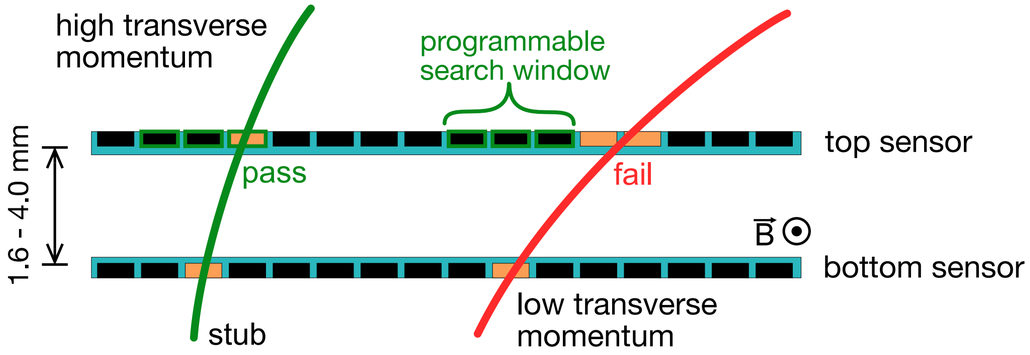


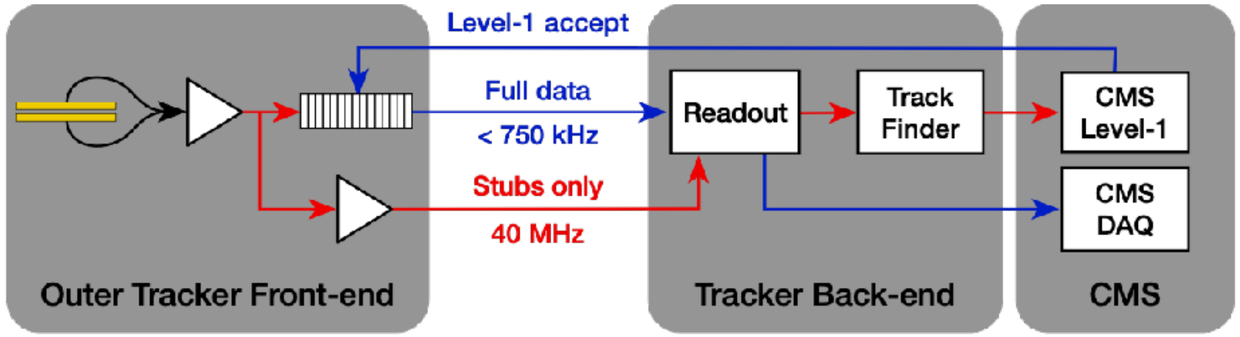
Layer 1 TBPS with flat and 2 straight sections

TEDD with 5 layers



CMS Module Concept

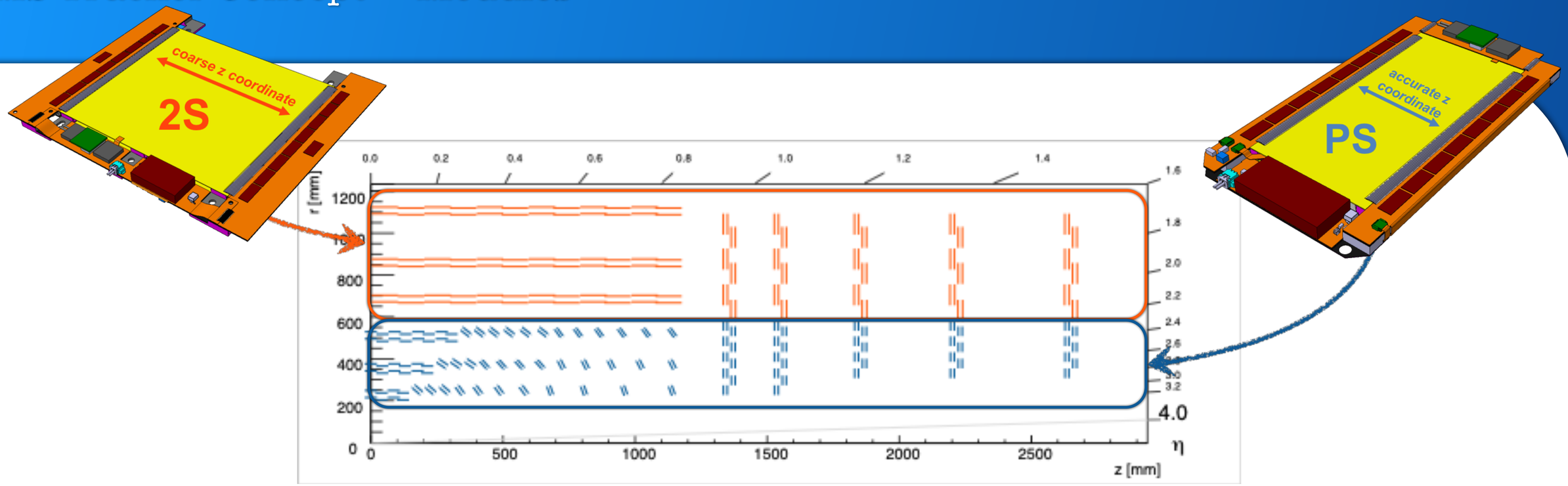




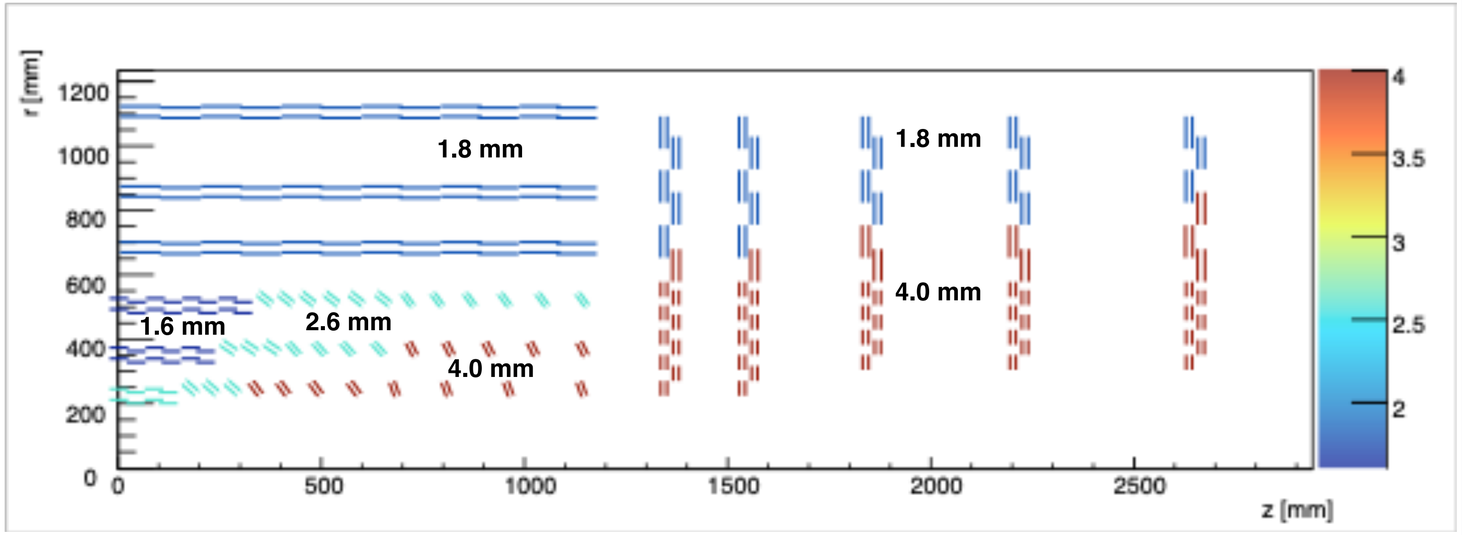
- exploit strong magnetic field of 3.8 T of CMS solenoid
- p_T discrimination on board:
  - two closely spaced sensors
  - correlate signals —> local p_T measurement
  - reject low p_T Tracks —> minimise data volume
- ‘stub’ is formed of signals found within search window

- ‘stubs’ provided on module level
- Level-1 and readout data provided
- ‘stubs’ are sent at each bunch-crossing (40 MHz)
- Full data are read out on trigger decision (<750 kHz)

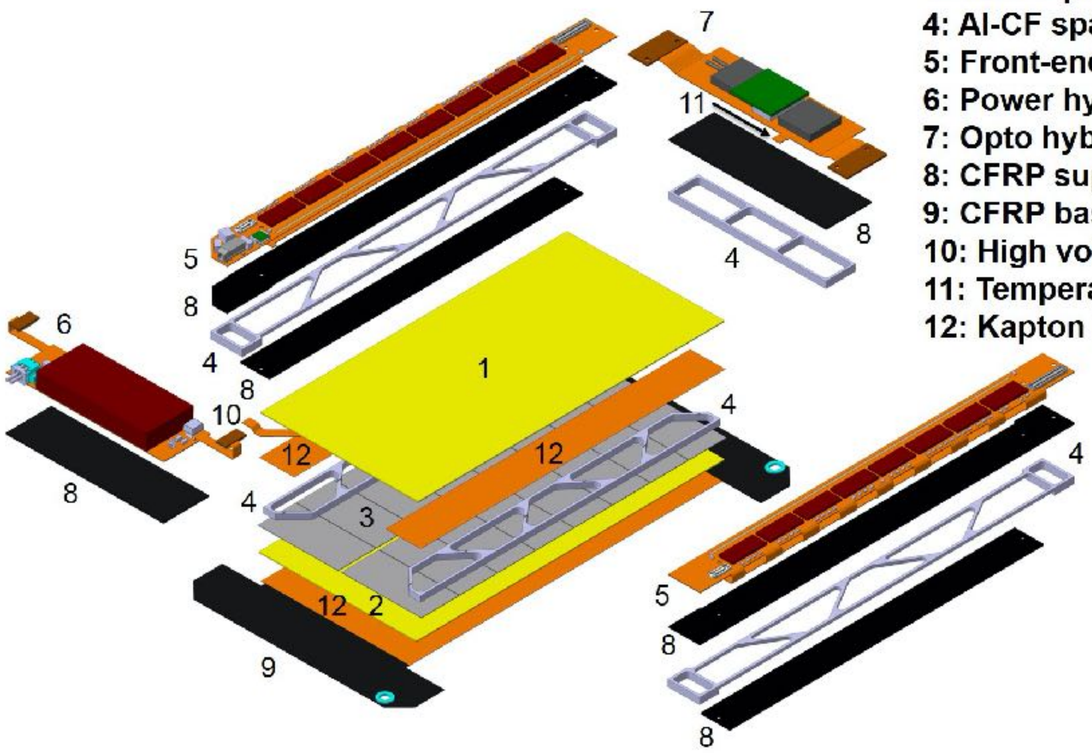
CMS Tracker Concept – Modules



- Two main types of modules:
  - 2S with two strip sensors
  - PS with one strip and one pixelated sensor
- variants differ in sensor spacing
  - arranged to optimise p_T discrimination vs. geometrical position in Tracker

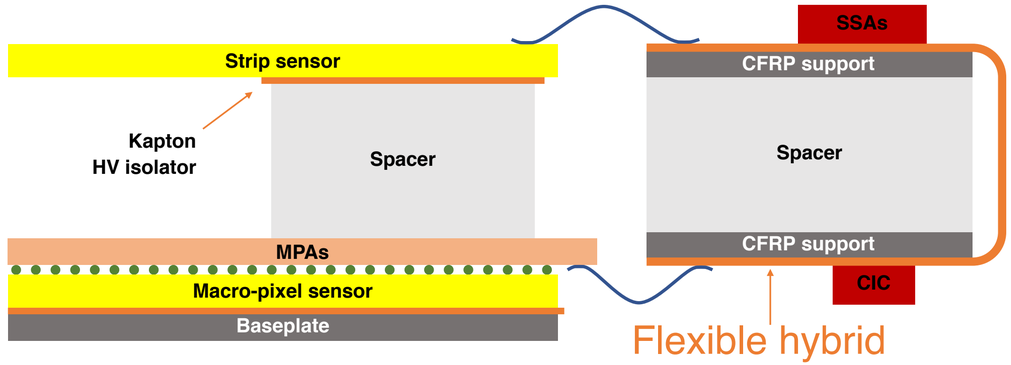


Example: PS Module



DESY will build 1500 of these modules

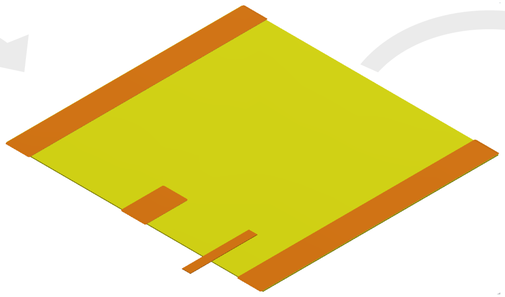
- 2 x 960 strips of ~2.4 cm x 100 µm for PSs sensor
- 32 x 960 macro-pixels of ~1.5mm x 100 µm for PSp sensor
- Front-end power ~8 W
- Sensor power ~1.4 W at -20°C
- MPAs and sensors are cooled through base plate
  - requires a large-area glue joint between pixel sensor and base plate



2S Module Assembly Sequence

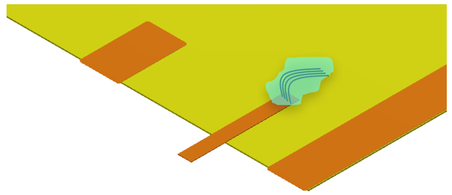
1. Glue polyimide HV isolation and attach HV tails on sensor backside

- Check dicing precision (metrology)



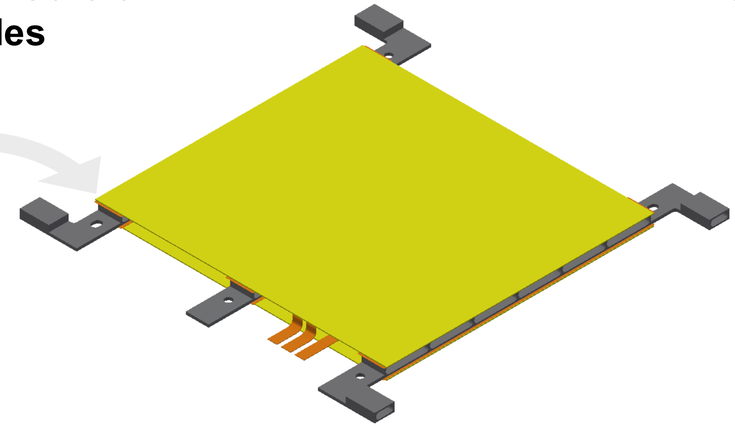
- Optical inspection

2. Wire-bond and encapsulate HV tails



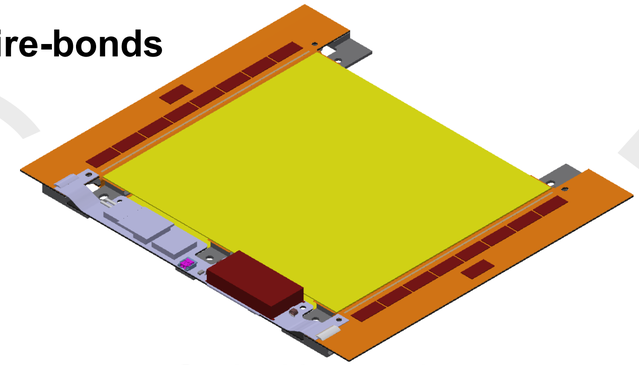
- HV test backside isolation
- Sensor I(V)

3. Glue sensors on Al-CF brides



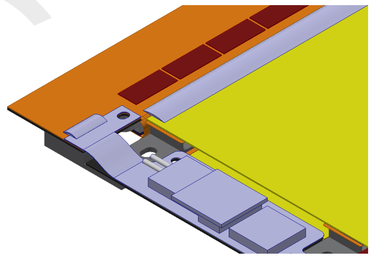
- Module metrology

4. Glue readout and service hybrids on bare module



- Optical inspection
- HV/LV test

5. Place ~4000 wire-bonds



- Module test

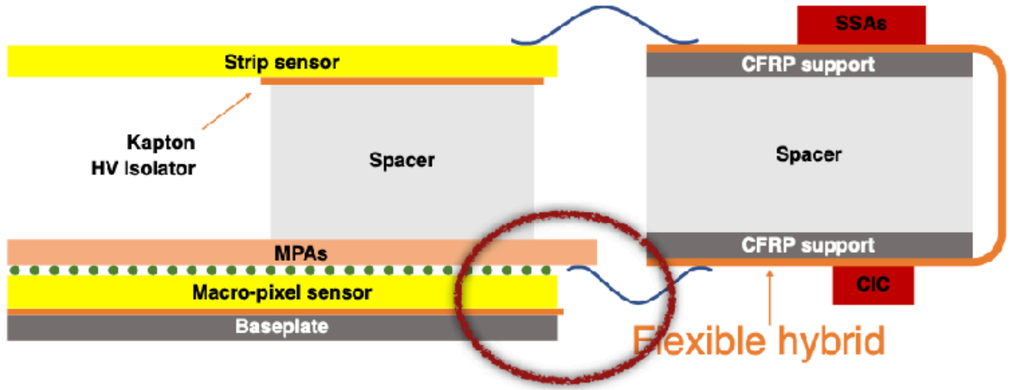
6. Encapsulate wire-bonds

- Module test

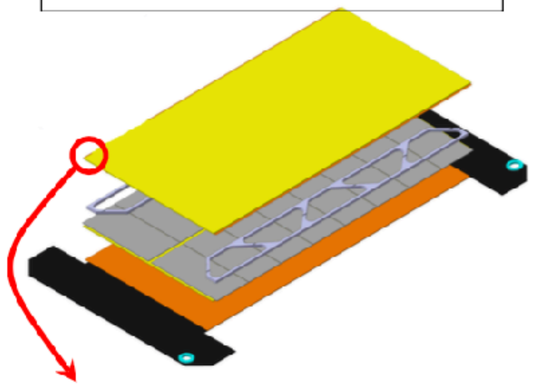
Automated assembly of PS Modules

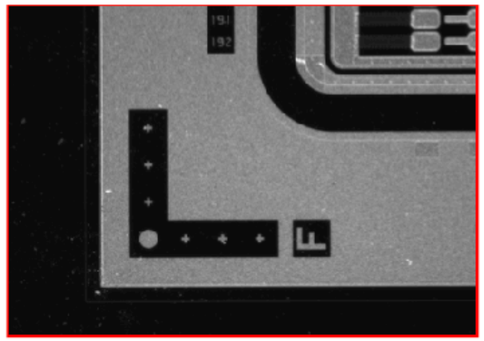
Why automate?

- Requirements on precision
- 300 µm overhang plus undersell are a challenge
- PSp and PSs sensor oriented upwards
  —> can look from top and see markers on both sensors



tolerance on PSp-PSs alignment: 800 μrad

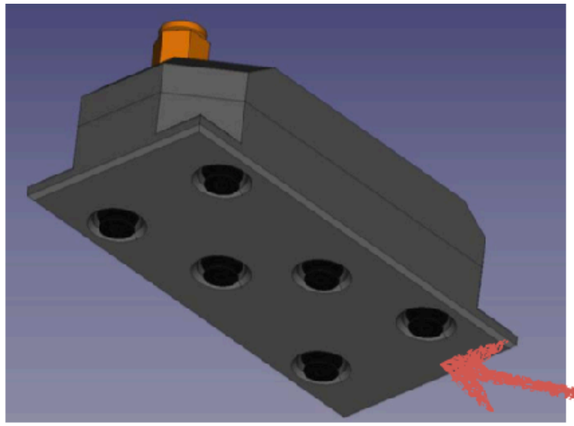




What to automate?

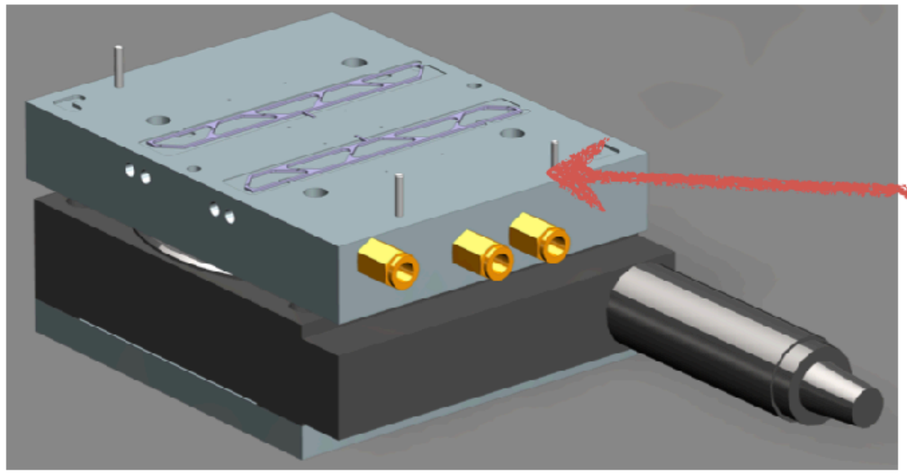
- high-precision steps of assembly:
  - **baseplate + MaPSA + spacers + PSs**
- use high-precision markers on sensor corners and precise mounting jig with markers
- PSp sensors edges extended by 300 µm wrt. PSs
  —> both corner markers visible from top
  one camera sufficient
  metrology 'built in'

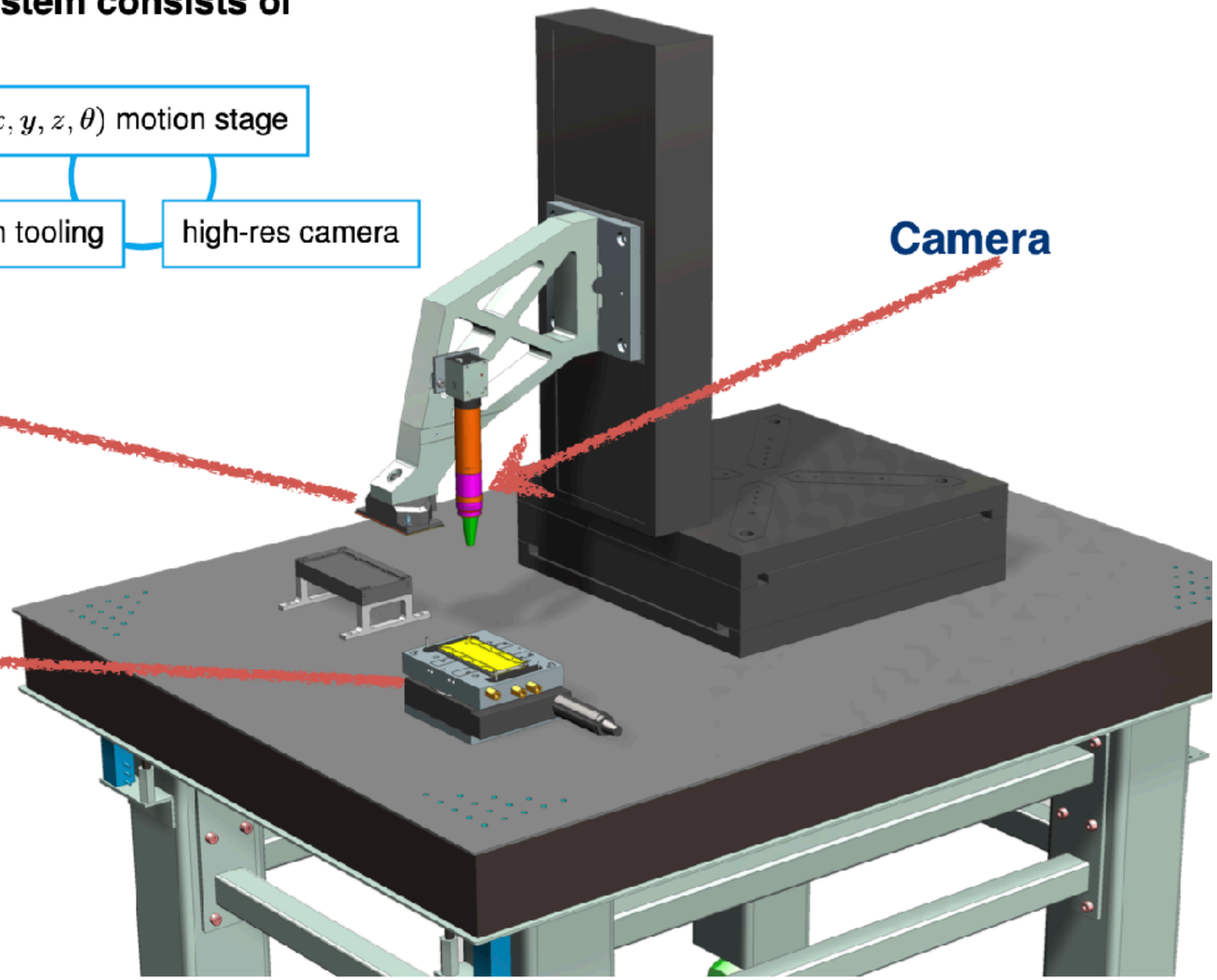
Automated Assembly of PS Modules



system consists of

- (x, y, z, θ) motion stage
  - vacuum tooling
  - high-res camera





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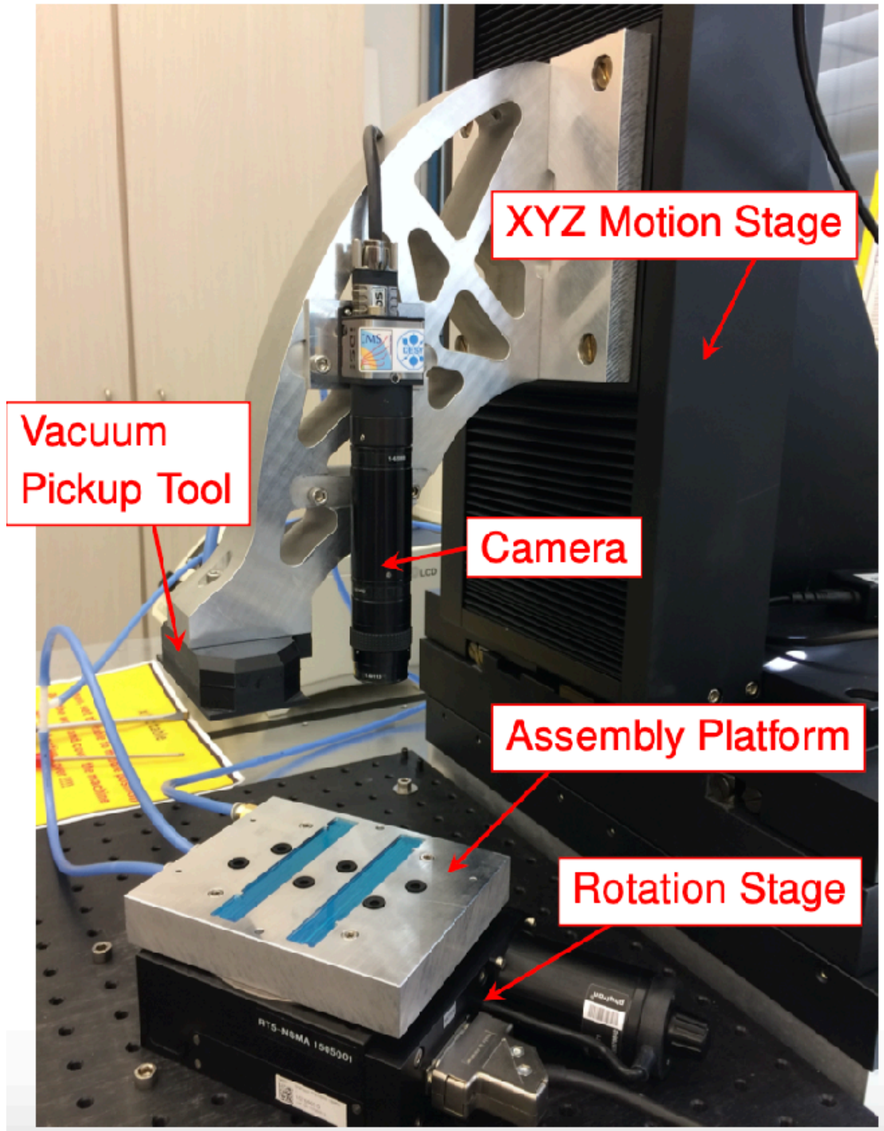
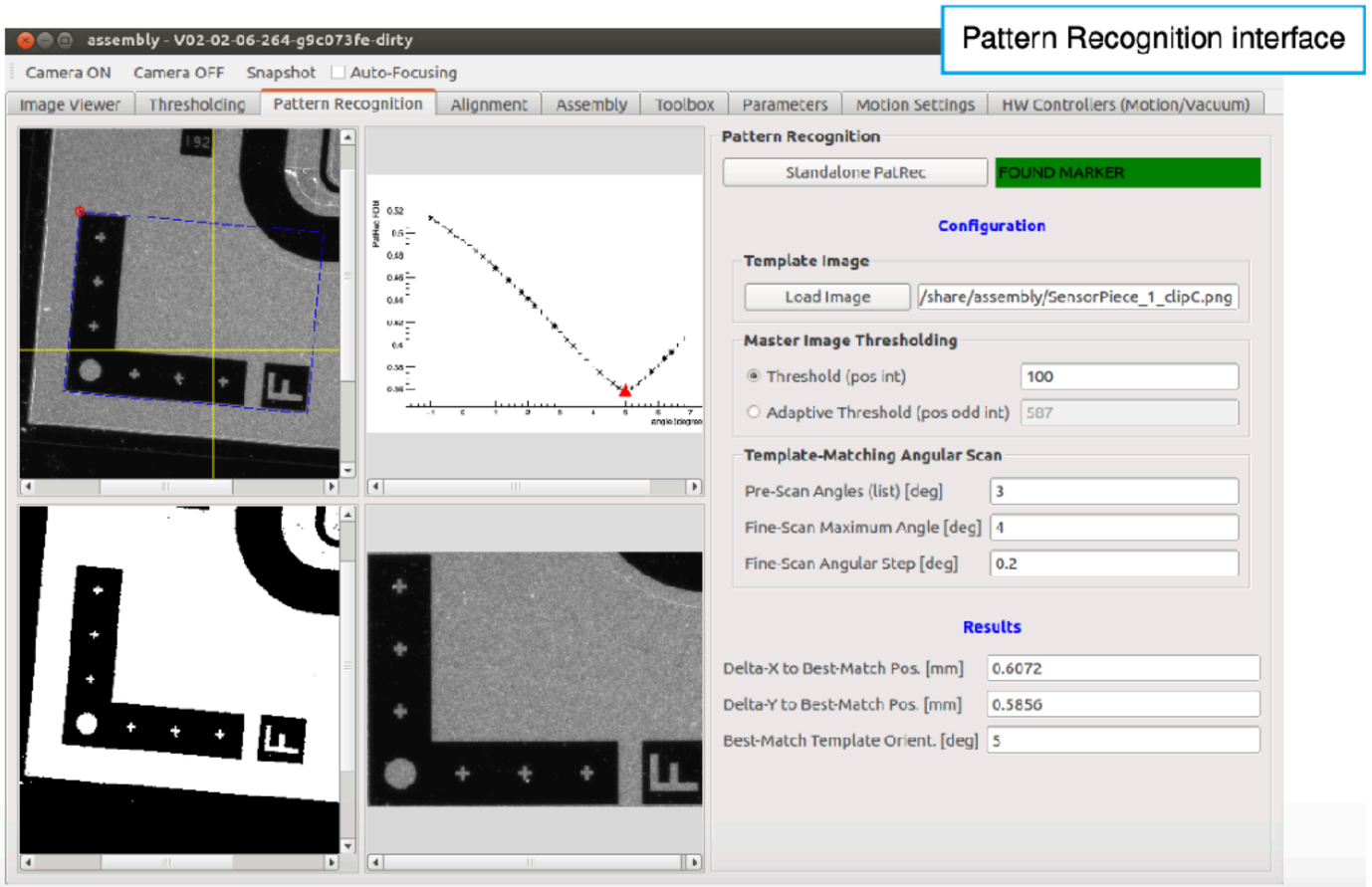
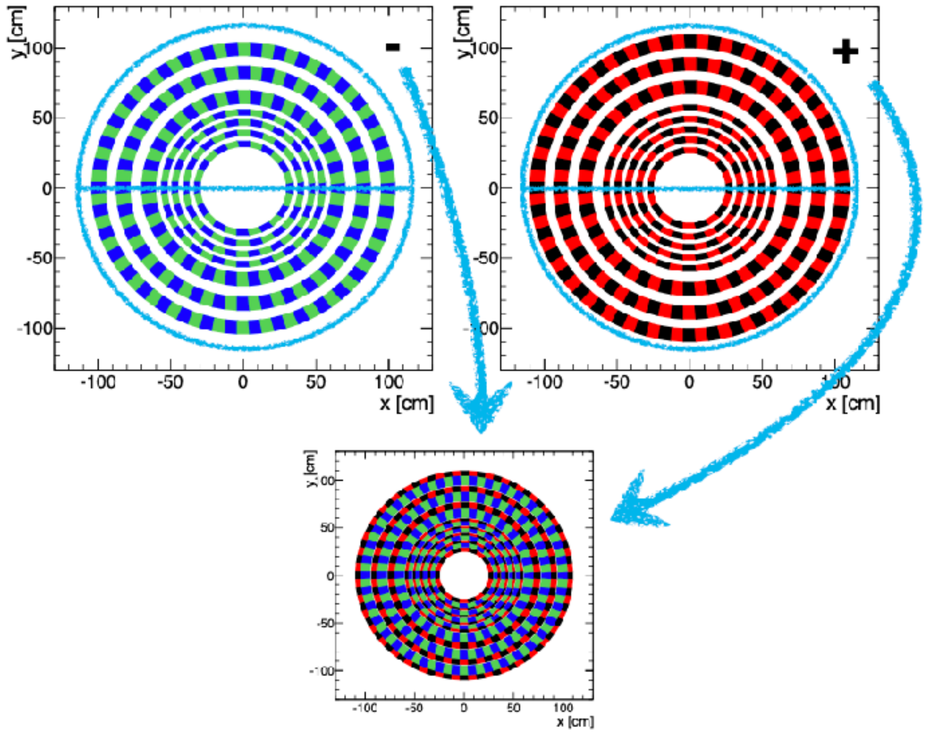
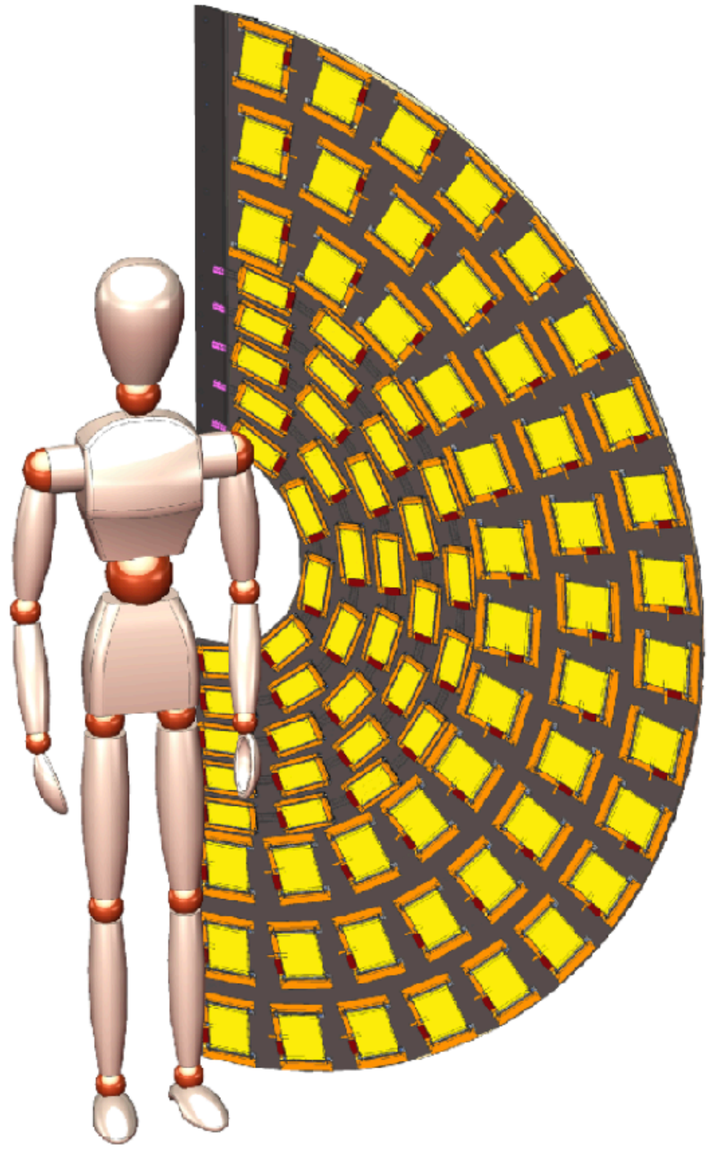


- Dedicated software developed to control motion, vacuum, image acquisition
- need to use small amounts of fast-curing glue (epoxy) to allow for handling (R&D ongoing)

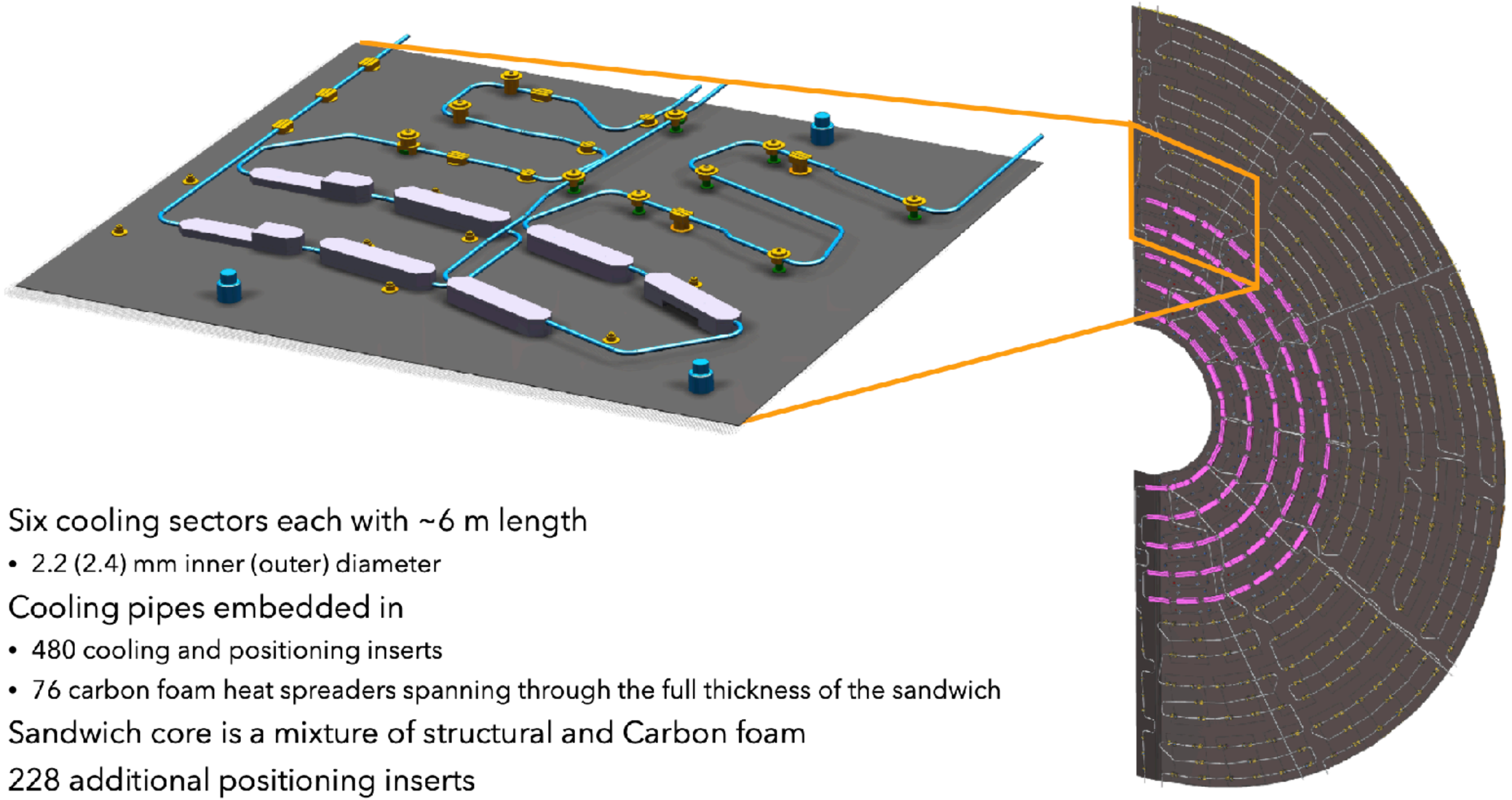


How to puzzle it all together





- Backbone is a carbon fibre sandwich half-disk structure (Dee)
  - ~225 cm in diameter
  - 10 mm thickness
- Modules are mounted from both sides onto structure
  - O(300 µm) positioning precision
- 20 Dees are combined to build one TEDD
  - 150 cm total length



- Six cooling sectors each with ~6 m length
  - 2.2 (2.4) mm inner (outer) diameter
- Cooling pipes embedded in
  - 480 cooling and positioning inserts
  - 76 carbon foam heat spreaders spanning through the full thickness of the sandwich
- Sandwich core is a mixture of structural and Carbon foam
- 228 additional positioning inserts

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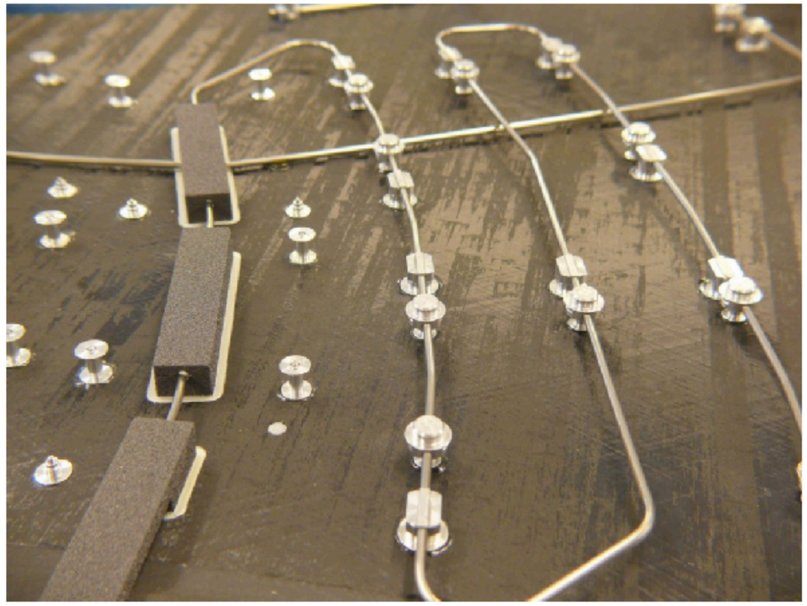
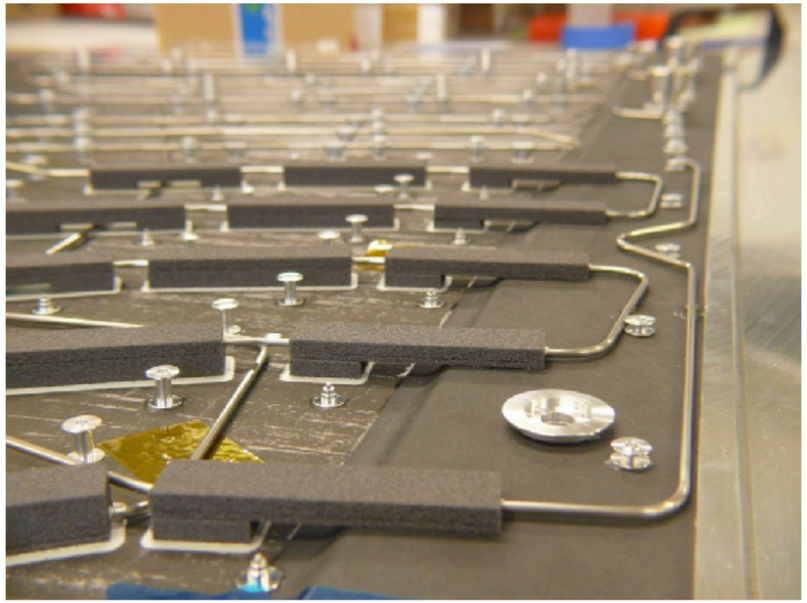
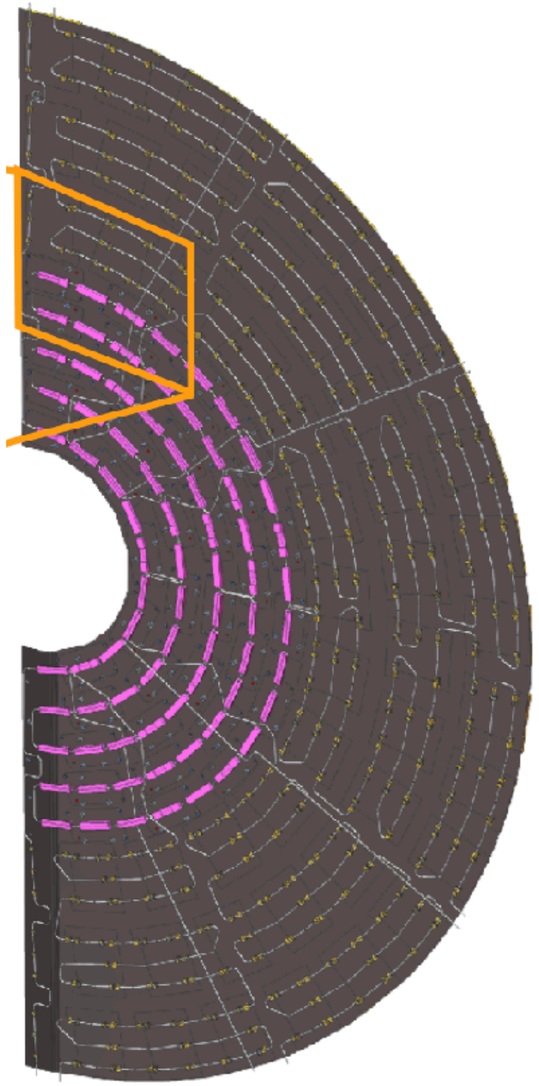
Develop with industry the procedure to construct a Dee







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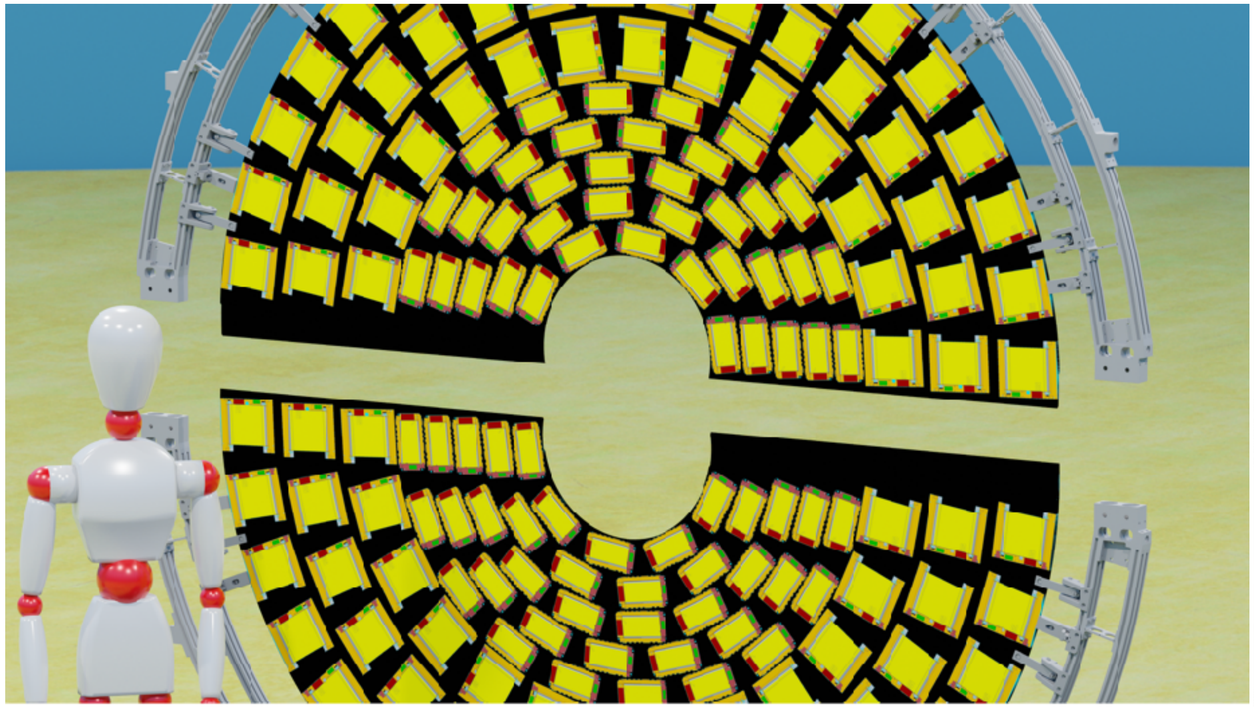
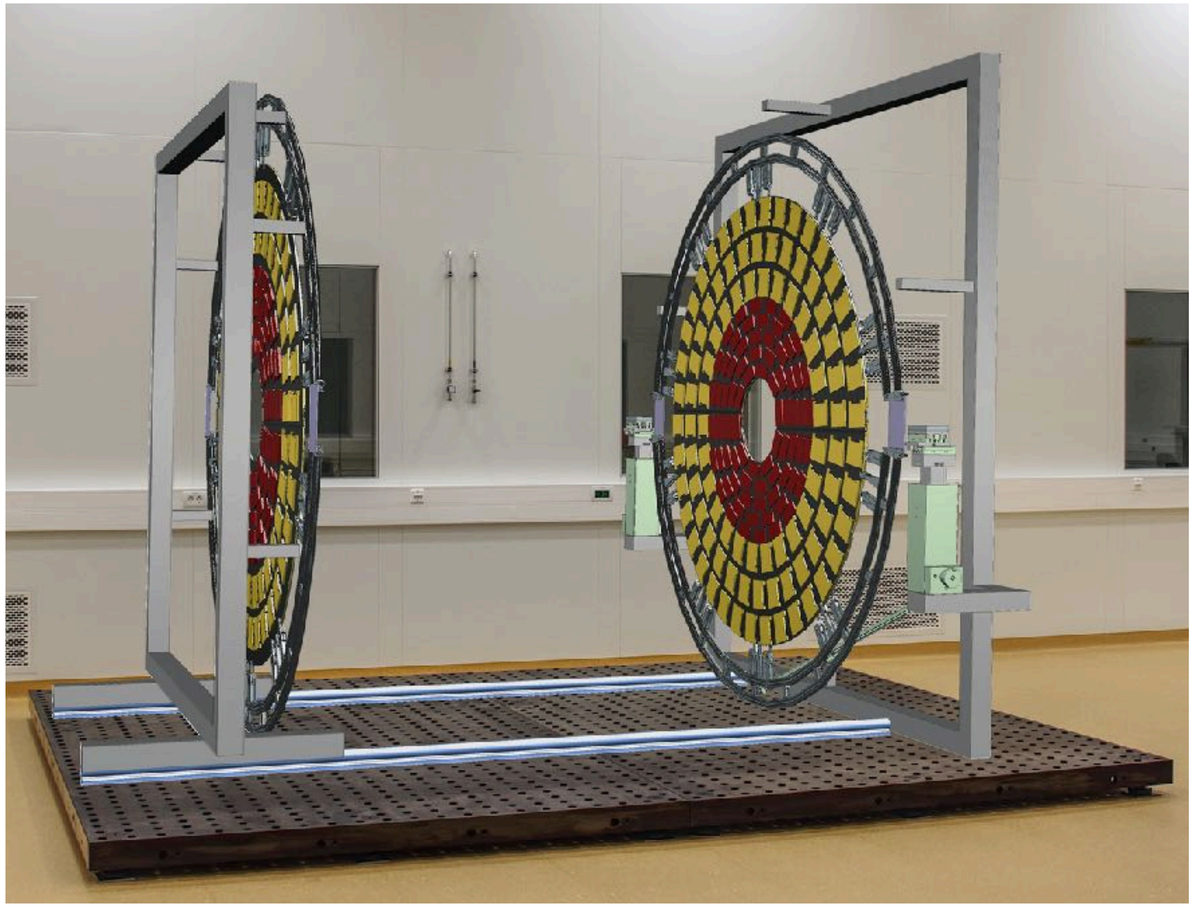
From the Dee to the Endcap





Dee —> Disk —> Double-Disk

Assembly of an End-cap

5x Double Disk and a lot of service routing —> Endcap