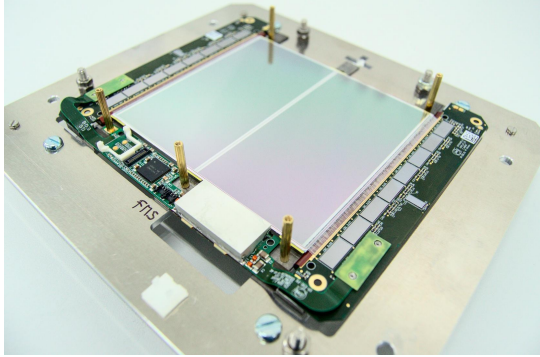
IIHE Annual Meeting
15.11.23



Phase-2 CMS Tracker Upgrade

Yannick Allard, Wim Beaumont, Martin Delcourt, Gilles De Lentdecker, Benoit Denegre, Pierre Dewulf, Jorgen D'Hondt, Denis Dutrannois, Laurent Favart, Tahys Janssen, Ali Khalilzadeh, Michael Korntheuer, Aloke Kumar Das, Steven Lowette, Inna Makarenko, Denise Müller, Eric Roose, Adriano Scodrani, Golnaz Sherafatipour, Laurent Thomas, Michael Tytgat, Pascal Vanlaer, Senne Van Putte, Yifan Yang

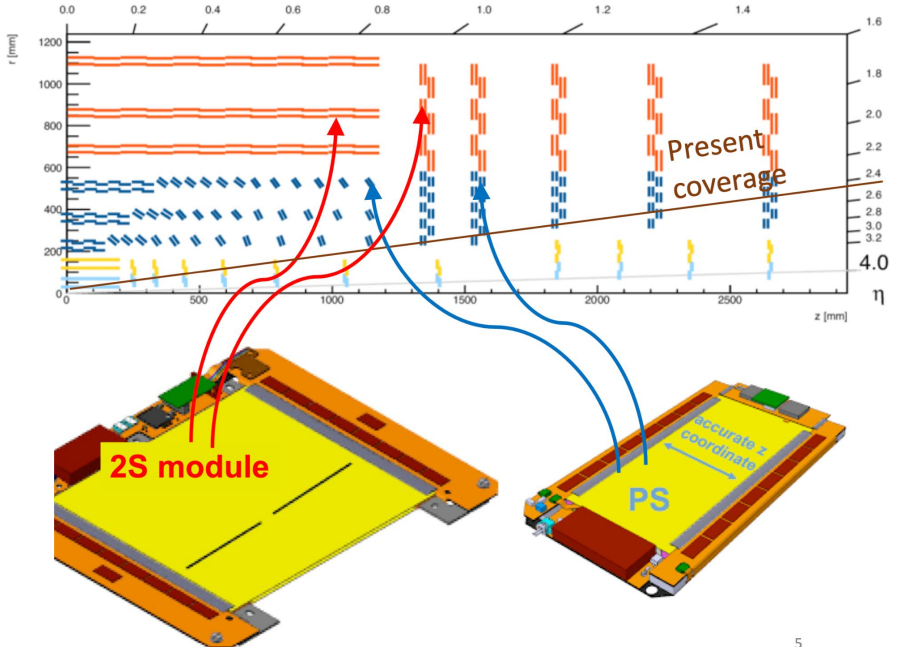
ULB UNIVERSITÉ LIBRE DE BRUXELLES

iihe BRUXELLES BRUSSEL

VUB VRIJE UNIVERSITEIT BRUSSEL

Universiteit Antwerpen

HL-LHC: CMS Phase II Tracker Upgrade



HL-LHC:

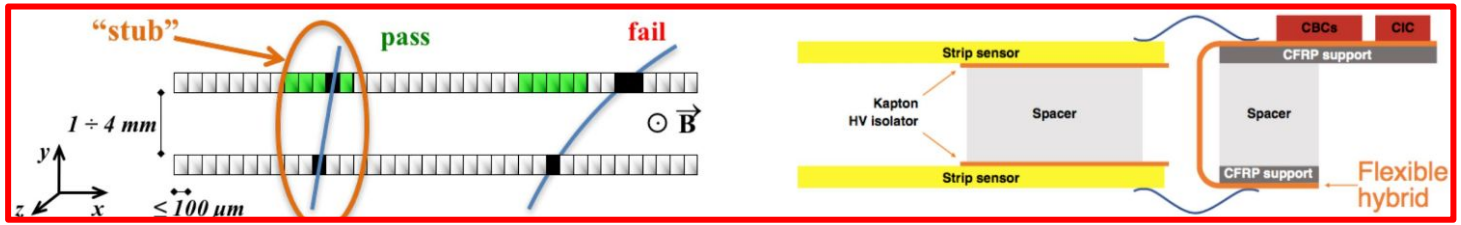
- 5-7 times higher beam intensity
  →An integrated luminosity of 3000 fb^{-1}
  →Pile-up 140-220 collisions per bunch crossing

Tracker requirements:

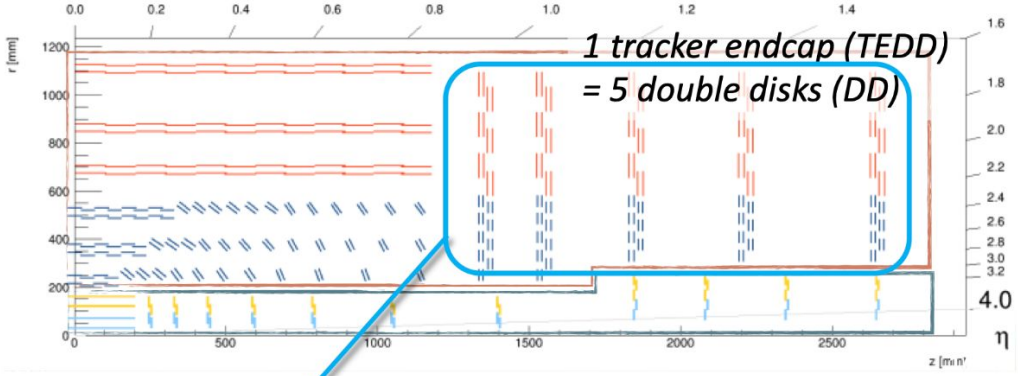
- Radiation-hard tracker is required
- Angular coverage to be extended close to the beams

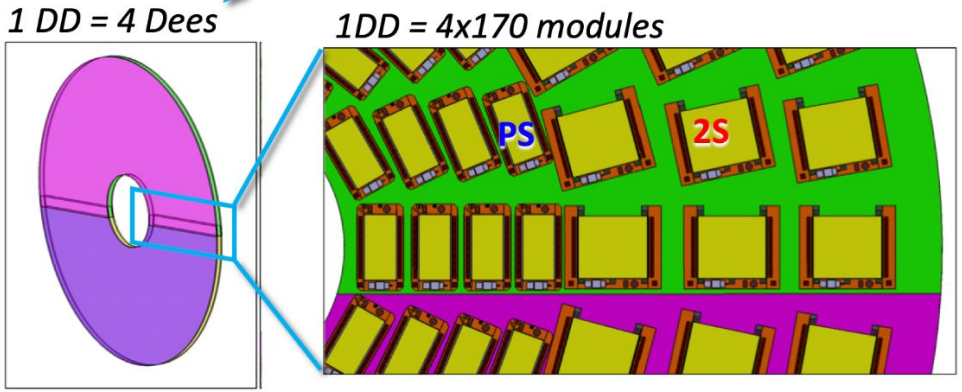
Tracker features:

- Outer tracker will provide correlated hit pairs, "track stubs", read out at 40MHz, for real-time event filtering (level 1 trigger)



Belgian contribution: lead the construction of one endcap





- TEDD unit consists of five double-discs
- Each double-disc consists of four dees

✓The modules are mounted on discs, which for assembly reasons are split in half-discs, or “dees”

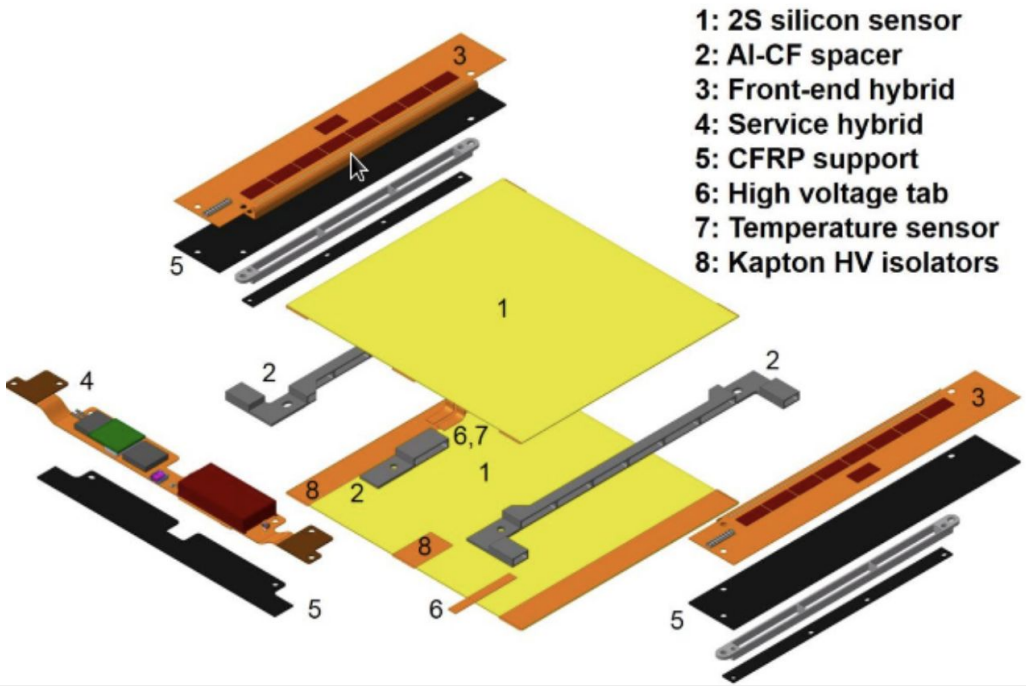
✓Two discs are grouped to form one double-disc, which provides one hermetic detector plane

✓Ten double-disc units will be produced, five for each endcap

✓To accommodate the change in diameter of the Inner Tracker support tube, the TEDD discs need to be of two different inner radii

- ***DEES and double-disks assembly will take place at UCLouvain***
- ***2S modules for this structure will be assembled at IIHE***

2S modules: design



- Two 10x10cm2 strip silicon sensors with pitch size of 90 microns and a few mm apart
- Spacers, made of AlCF, quite fragile, careful manipulation needed. The spacers' material is very special
  →to match the coefficient of thermal expansion of Silicon
  →to transfer heat from silicon and hybrids to cooling pipes
- Kapton foils for HV isolation
- The readout electronics and the powering scheme are custom-made
  →2 front-end readout hybrids
  →1 service hybrid

- The strips of the upper and lower detector need precise alignment, less than 400 μrad tilt
  →to precisely measure the incident angle of incoming particles
- The modules will be cooled to (-35°C)
  →to reduce leakage current due to radiation damage

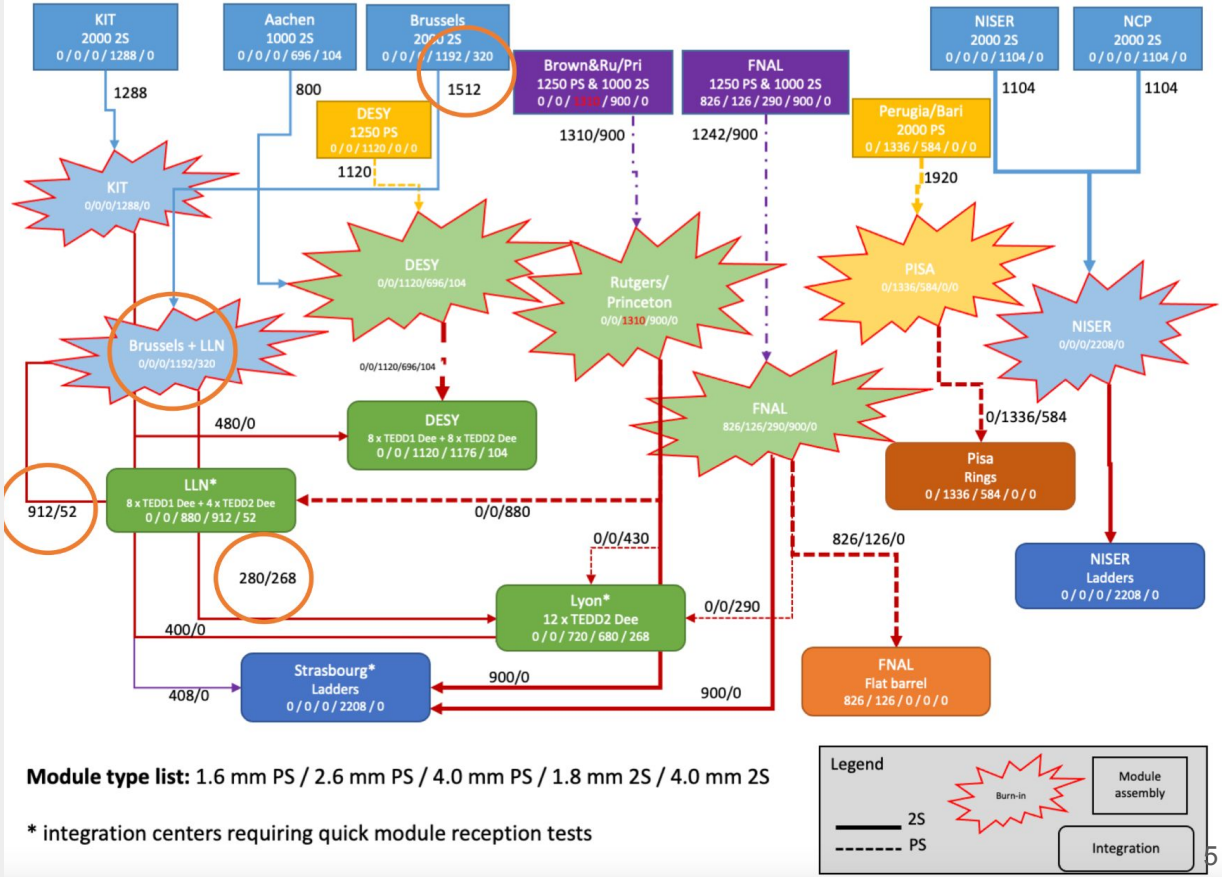
IIHE contribution

Assembly of ~1680 2S modules

- 1512 pledged 2S modules and additionally:
- 10% set aside as spares
- 1% of the modules that may have failed

IIHE is not only an assembly center but also a burn-in center:
→Prior to the integration into the structure, modules have to undergo a thermal cycling test

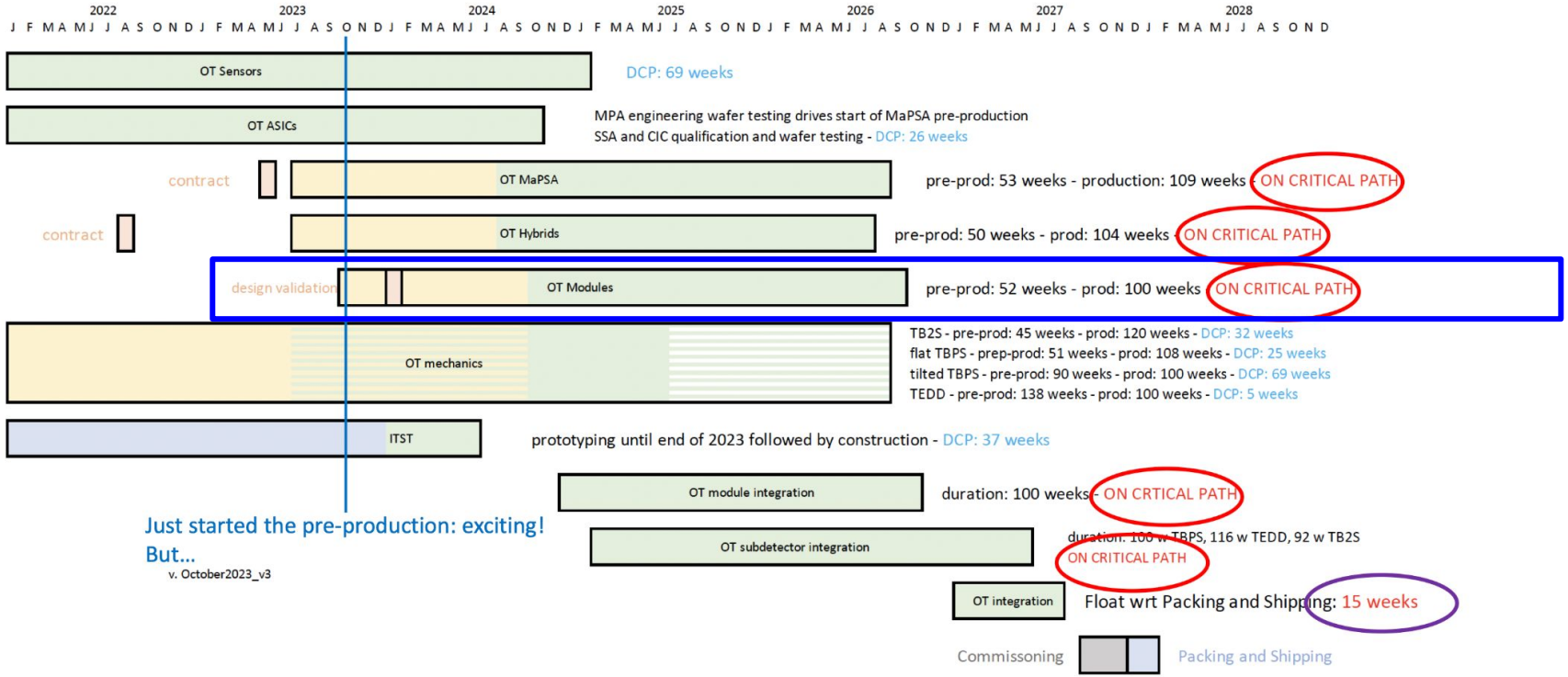
During production period our assembly line will have the capability to produce 2000 fully functional 2S modules of any type



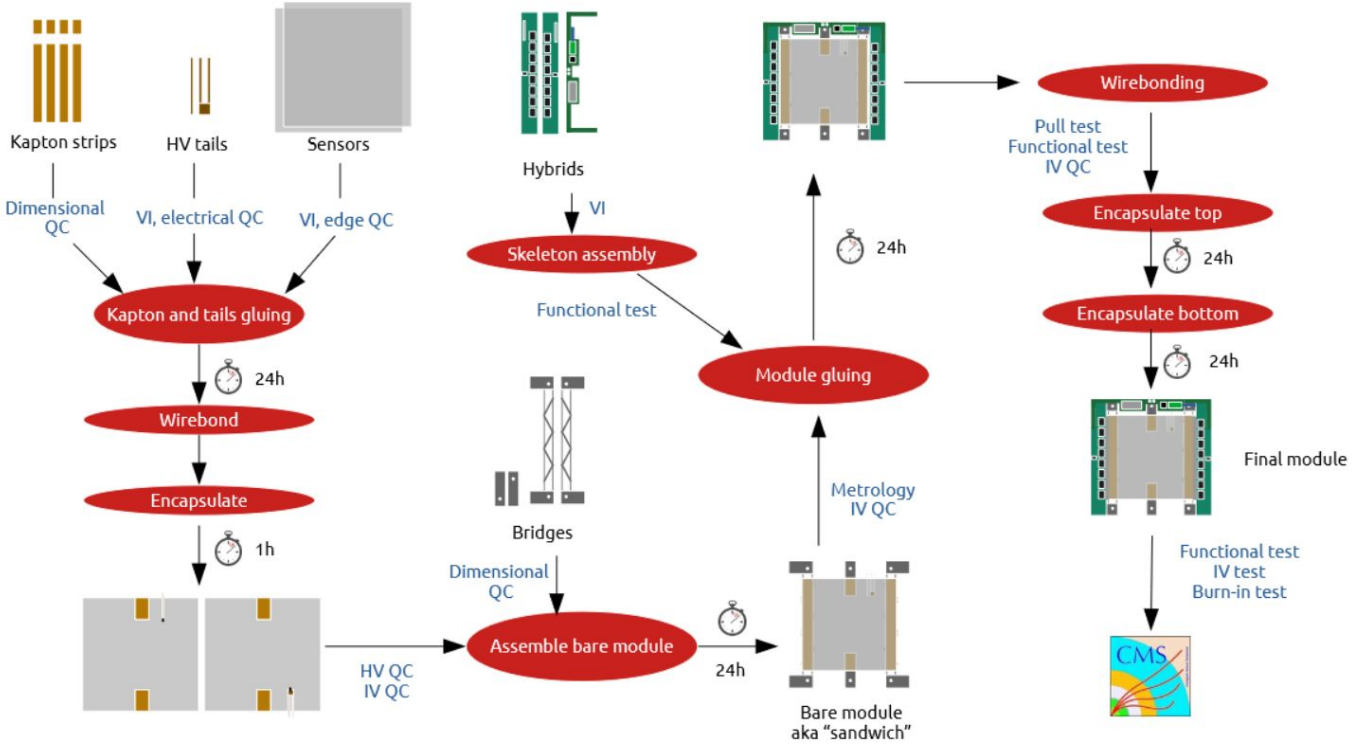
Calendar

- 2S Module ***pre-production*** & testing Q4 2023 - Q3 Mar 2024 : *52 weeks*
- 2S Module ***production*** & testing Q4 2024 - Q3 2026 : *100 weeks*

OT Schedule sketch



Assembly flow and steps

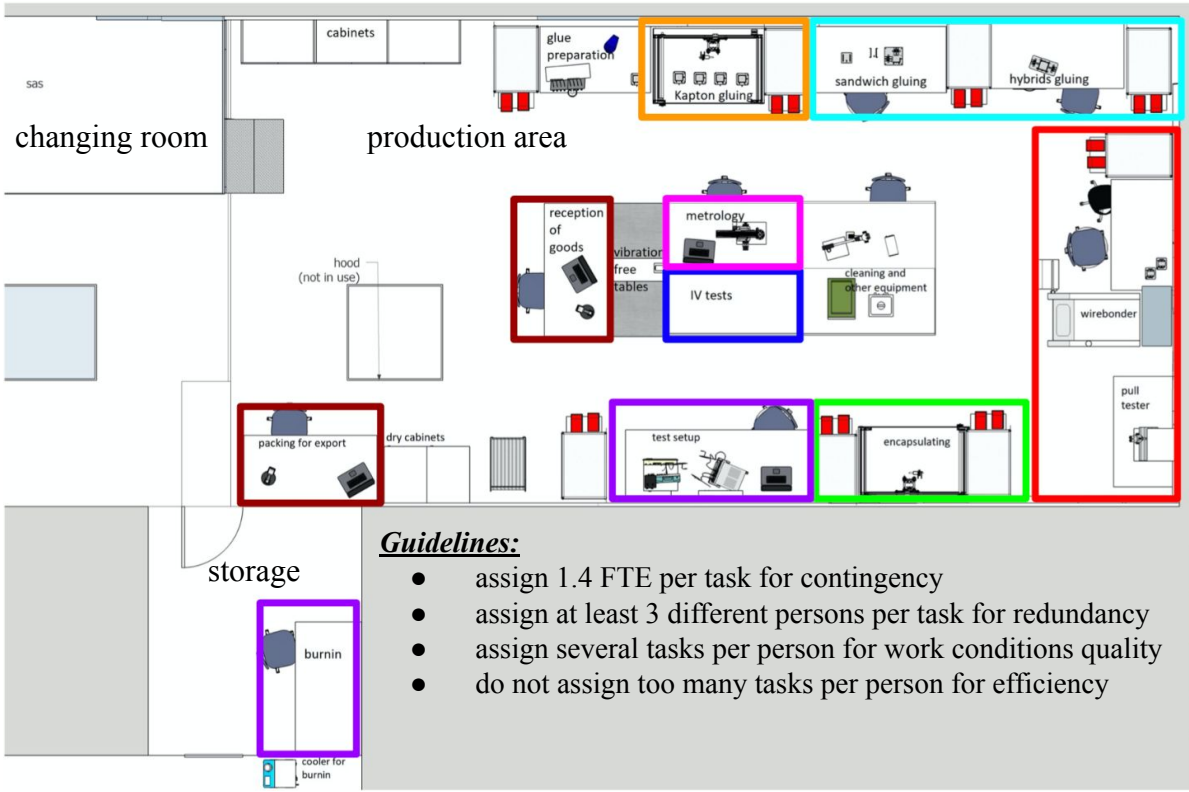


✓Except for the actual assembly itself, the process includes multiple validation and qualification control tests

- 1 module = 3500 euros = 10 assembly steps = 2 working weeks to assemble
- Peak production daily: completion 6 modules; 60 modules in assembly at different stages

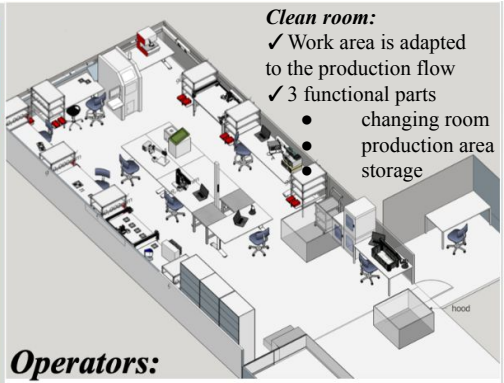
Production flow

During prototyping 12 modules of all types built
Timed construction for personnel needs → estimate: **~8 FTE operators + 40% contingency = 11(.2) FTE**



Guidelines:

- assign 1.4 FTE per task for contingency
- assign at least 3 different persons per task for redundancy
- assign several tasks per person for work conditions quality
- do not assign too many tasks per person for efficiency



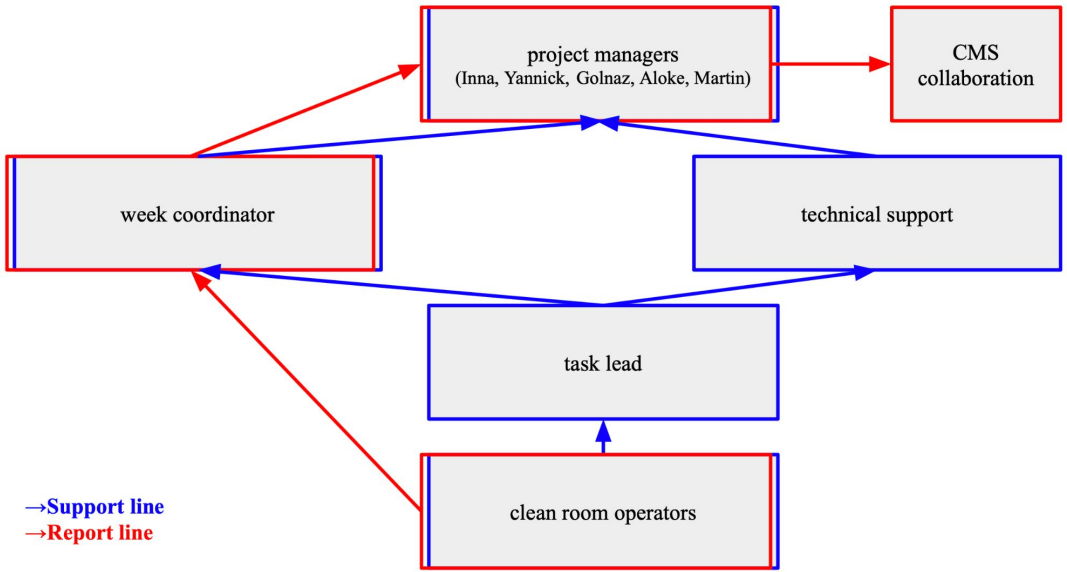
Clean room:

✓Work area is adapted to the production flow
✓3 functional parts
- changing room
- production area
- storage

Operators:

- Logistics operator (1 FTE)
- Kapton gluing (1 FTE)
- IV test operator (1 FTE)
- Manual gluing operator (1 FTE)
- Metrology operator (1 FTE)
- Wire bonding operator (1 FTE)
- Encapsulation operator (1 FTE)
- Readout tests operator (1 FTE)

Organisation chart



Project managers:
Individuals managing the smooth operation of specific segments of the assembly line

Week coordinator:
The individual overseeing module quality assembled during the week

Technical support:
Individuals tasked with resolving issues and offering technical support for specific matters

Clean room operators:
The assigned operator performs the designated assembly step on their assigned day
Nearly 30 individuals from four universities (Ghent University, UAntwerp, VUB, ULB) will participate in the assembly, encompassing technicians, engineers, physicists (postdocs), staff, and PhD students

Task lead:
The individual responsible for the task, the expert who possesses the most comprehensive understanding of its details

Getting ready to production

"One can conclude that good 2S modules do exist.

[BEL #3] seems to be one of them. Why is it so good?"

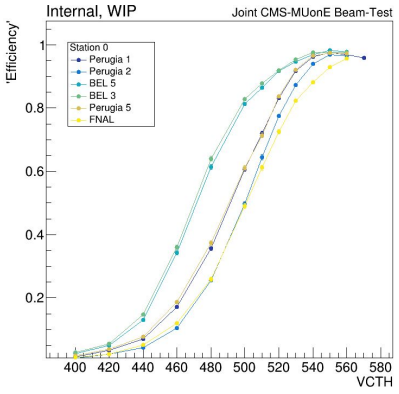
★★★★★

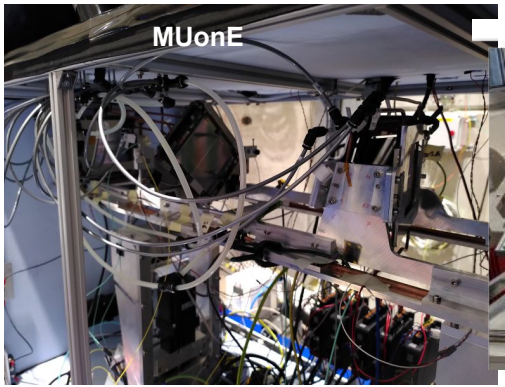
A total of **twelve modules** were assembled at the institute

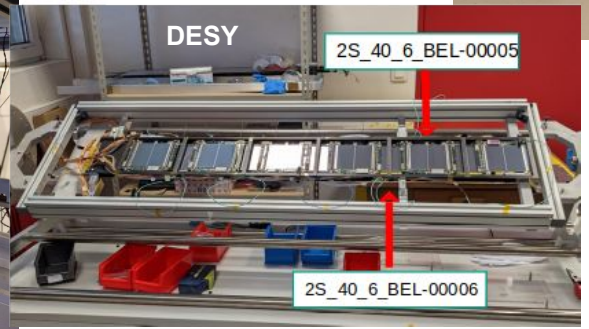
- Two early versions, six prototypes and four "kick-off" modules

Overall, very good quality modules, mostly within specs!

- Distributed and re-used within the collaboration:
  - ➢ Louvain-La-Neuve test bench & burn-in station
  - ➢ DESY integration test
  - ➢ CERN cosmic rack
  - ➢ MUonE experiment test run







Stay tuned!