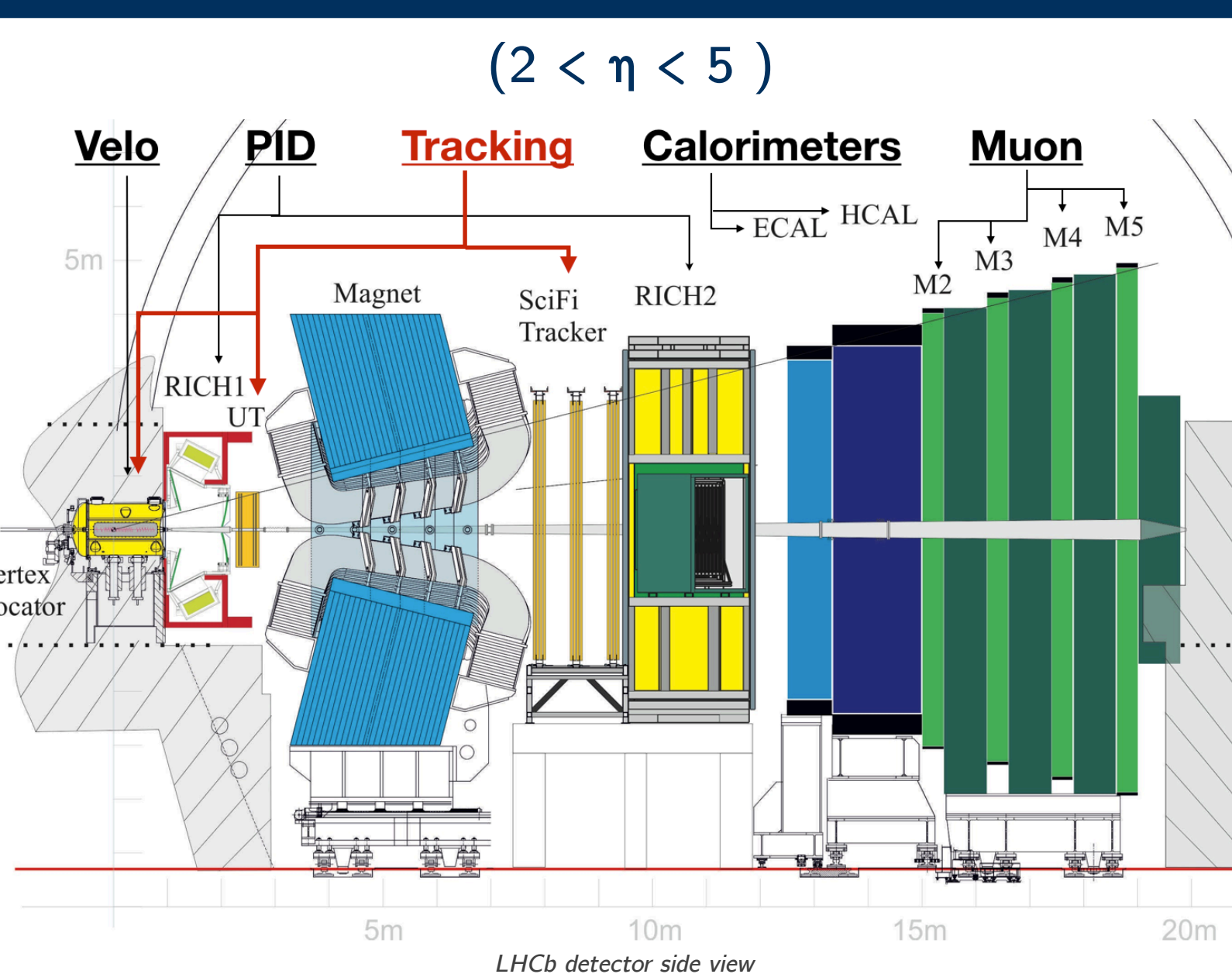


LHCb and its upgrade



Single arm forward spectrometer to study *b* and *c* hadrons.

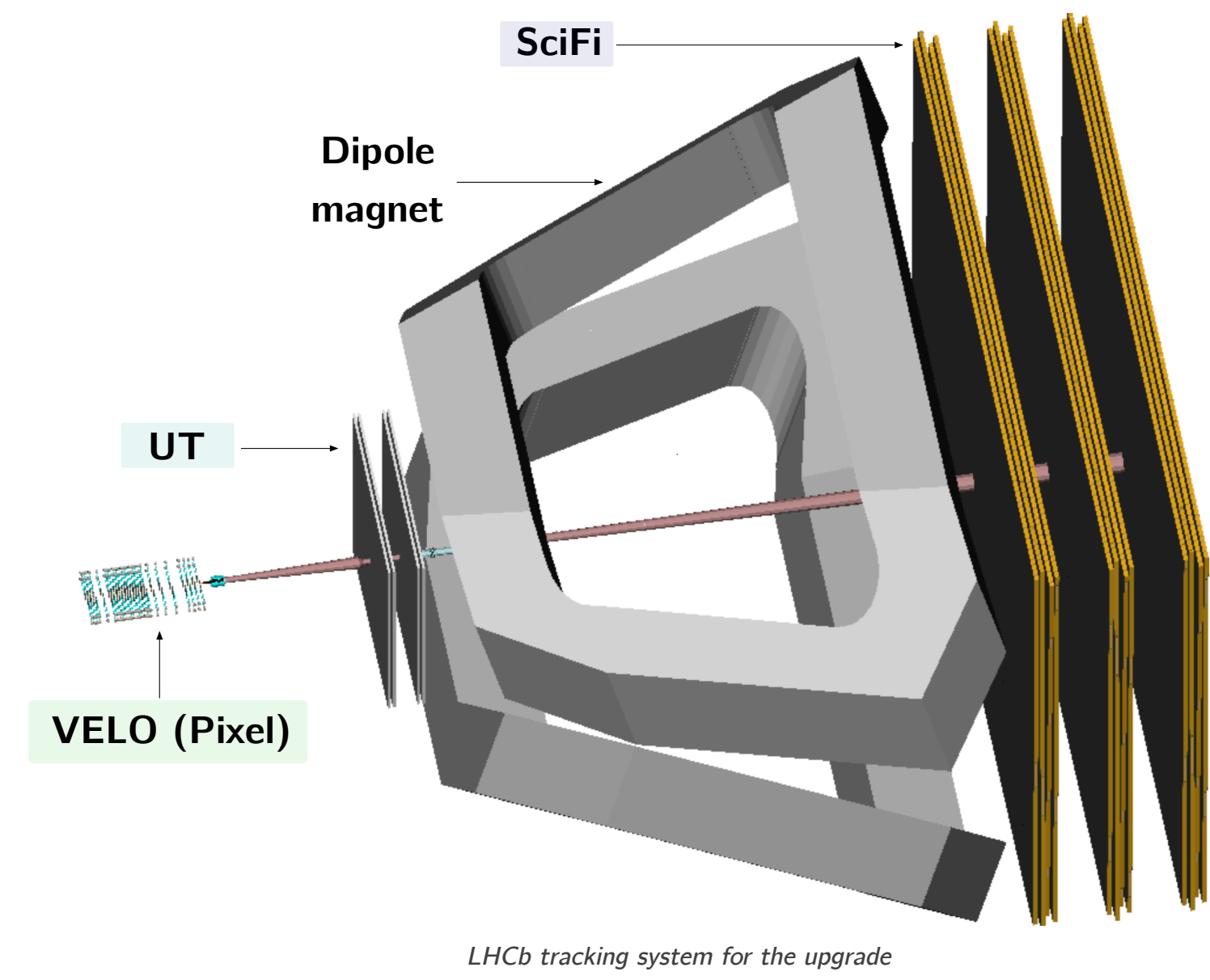
During LS2 (2018-2020) the whole tracking system will be upgraded to cope for the challenging conditions in Run III:

$$\mathcal{L}_{inst} = 2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1} (\times 5 \text{ Run II})$$

- Higher pile-up
- Higher spillover
- High occupancy
- Aging (at least $\sim 50 \text{ fb}^{-1}$)

Bottleneck for physics [1] from actual L0 HW trigger ($40 \rightarrow 1 \text{ MHz}$ read-out limit):

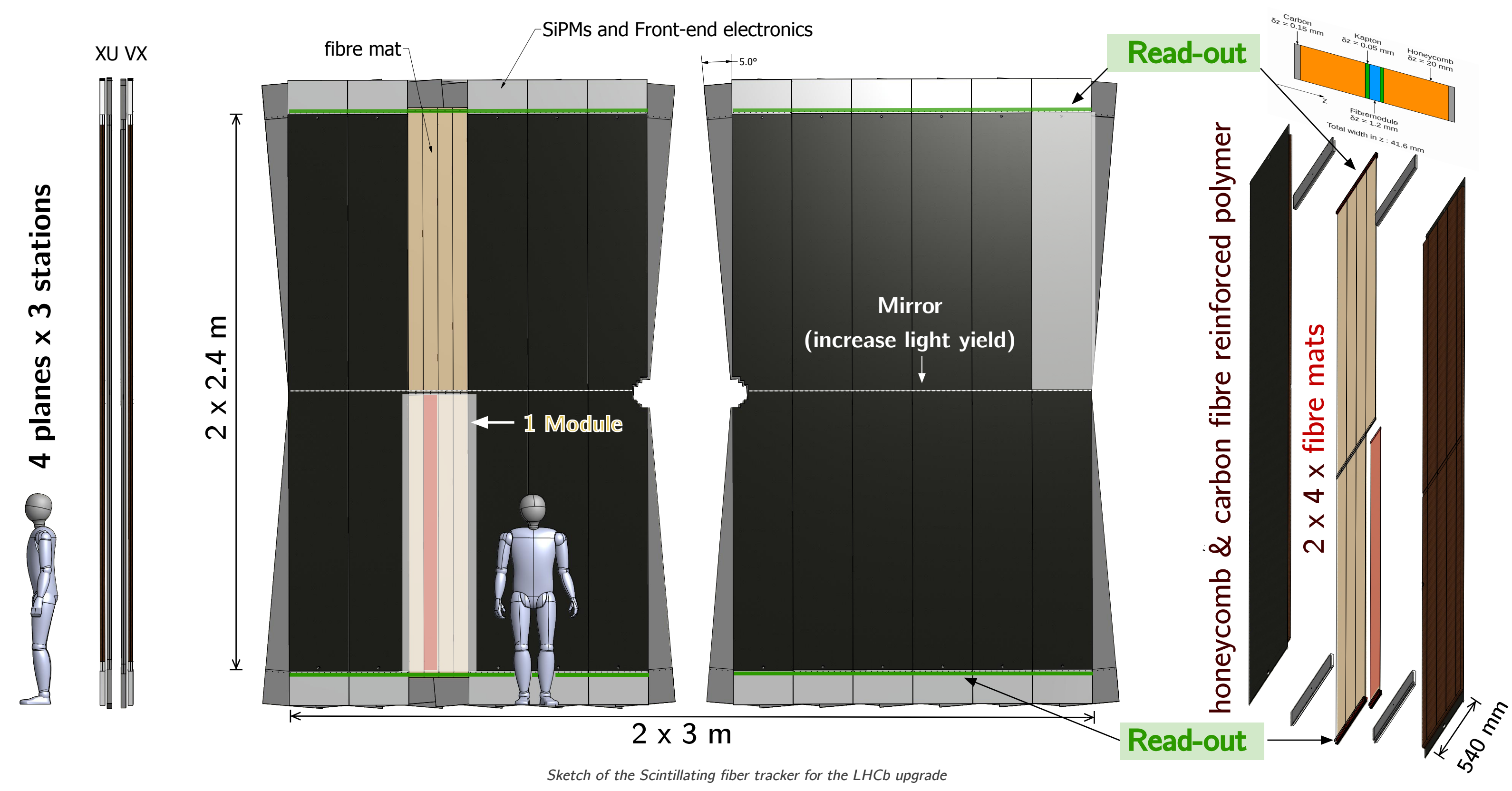
- Triggerless read-out system and full software event reconstruction at collision rate (40 MHz)!



Downstream tracker replaced by twelve layers of scintillating fibre tracker (SciFi) read-out by SiPM [2]

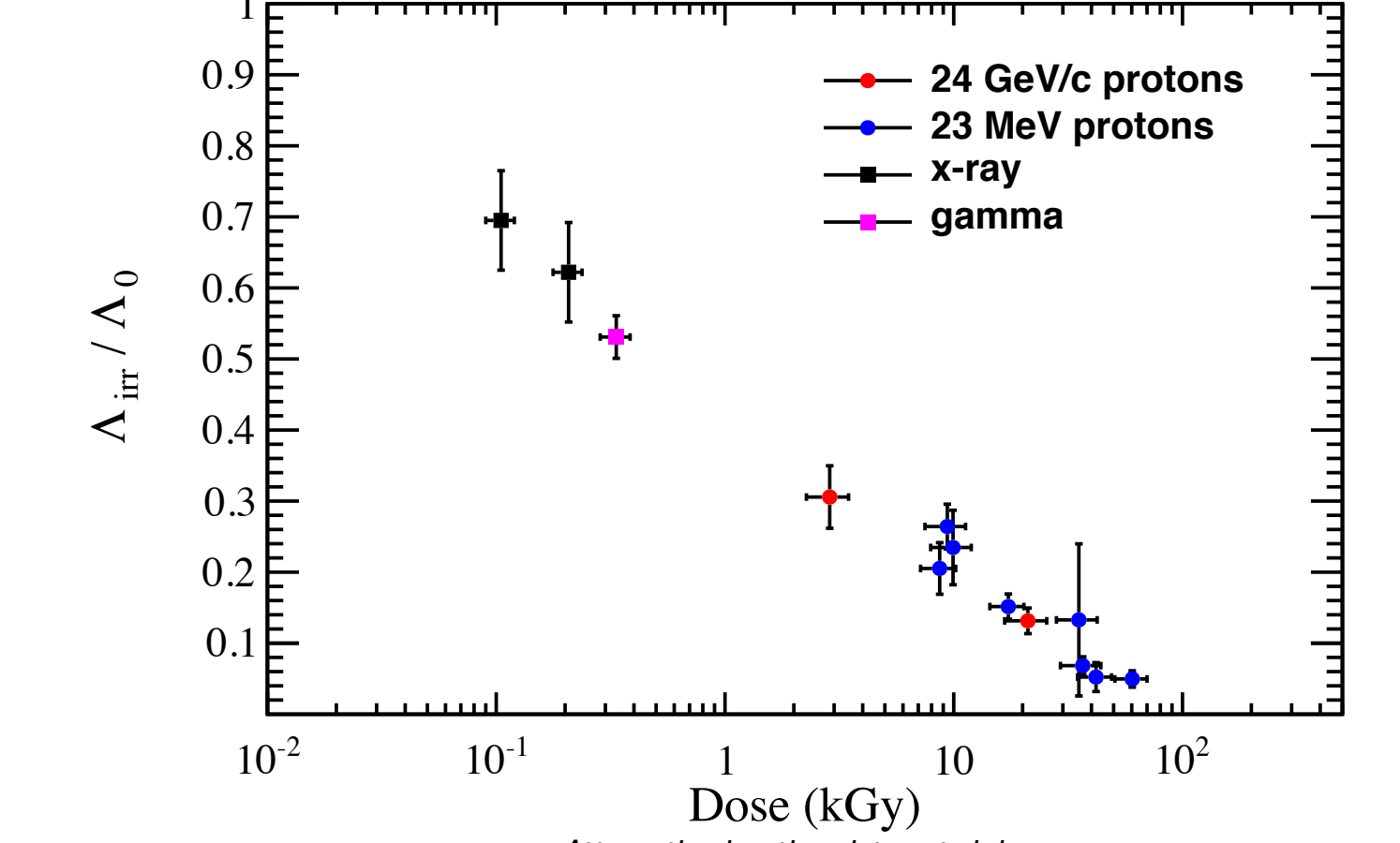
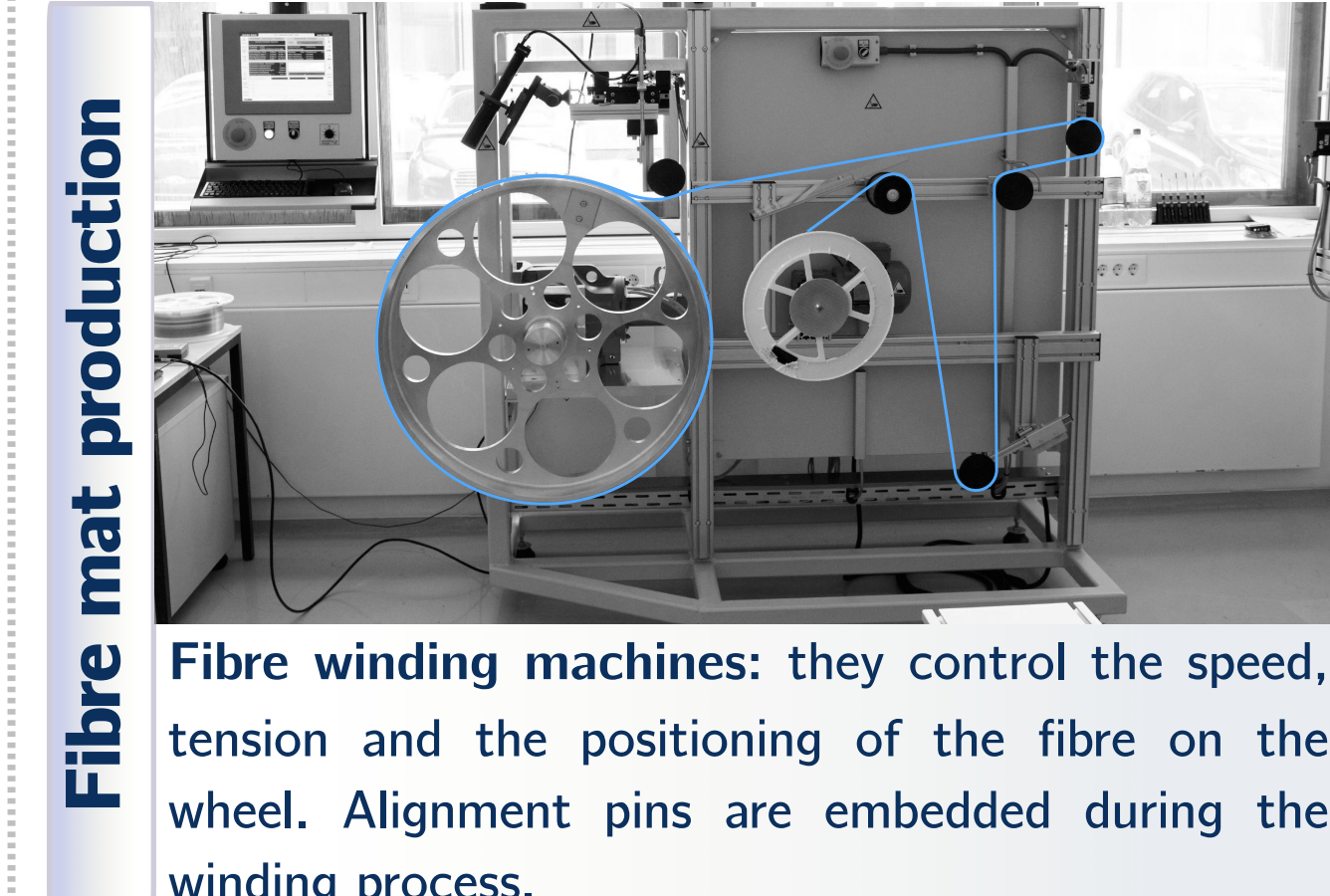
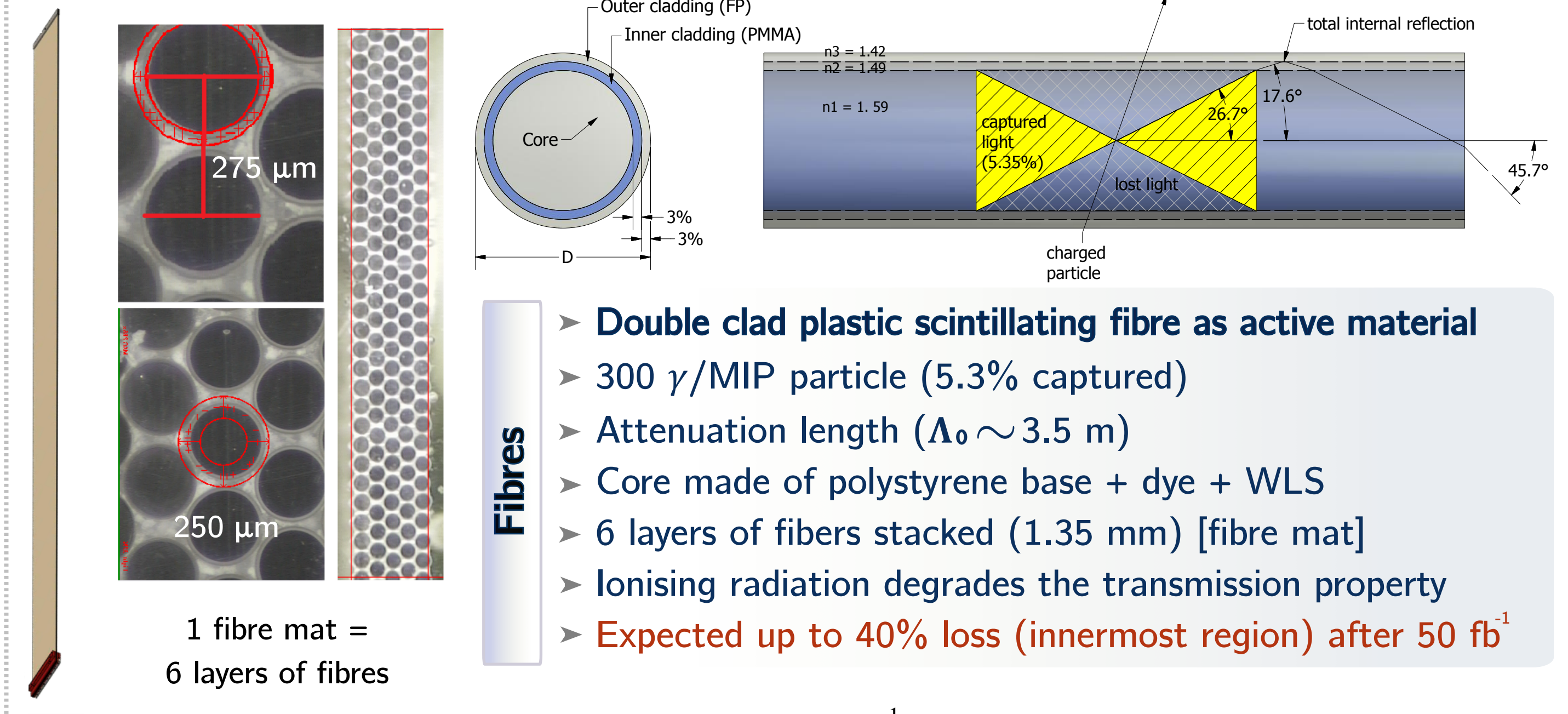
- Read out outside acceptance
- Single technology
- Easy to operate
- High granularity
- Uniform material

Scintillating Fibre Tracker (SciFi)

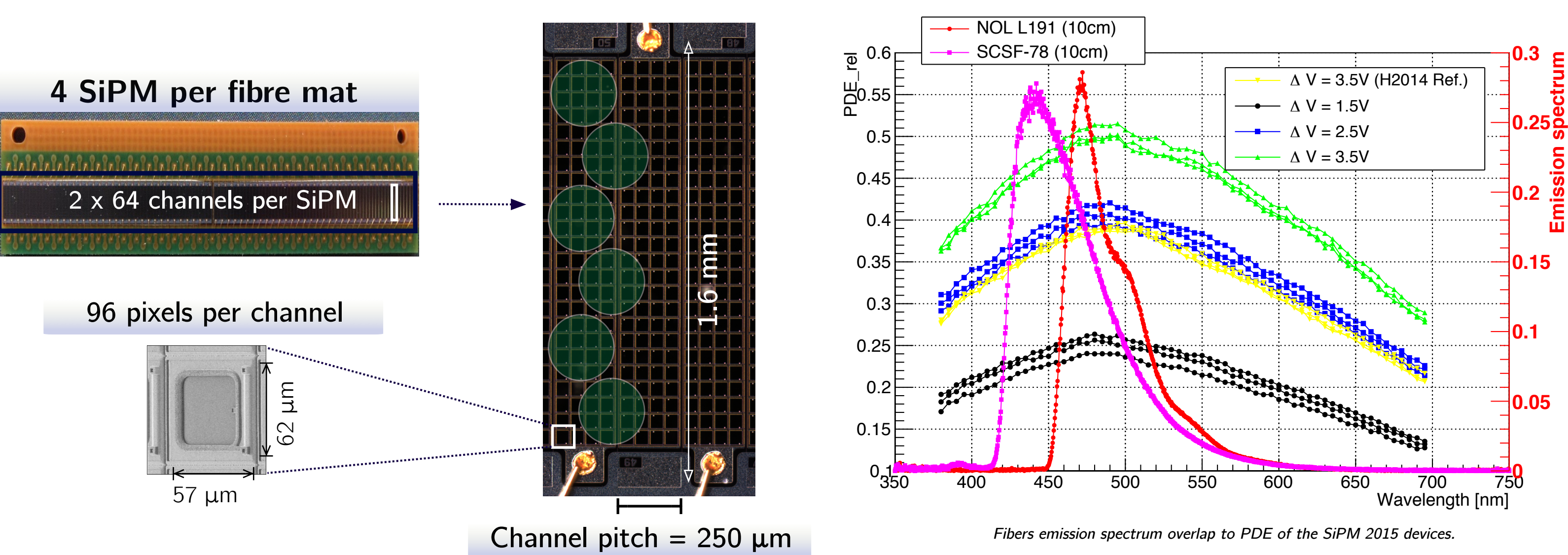


- Layout**
- 3 stations x 4 detection planes
 - 10/12 modules per detection plane
 - 16 SiPMs/module (530 mm width)
 - SiPM, FE electronics and services in a Read-Out Box
- Requirements**
- Resolution $< 100 \mu\text{m}$ (bending plane)
 - High detection efficiency (99%)
 - Low noise ($< 10\%$ signal rate)
 - $X/X_0 < 1\%$ per layer
 - 40 MHz readout without deadtime
- SciFi numbers**
- 128 modules
 - 360 m² total area
 - $> 10,000 \text{ km}$ of fibres
 - 550k SiPM channels
 - Operations up to 50 fb^{-1}

Fibres and Fibre Mat

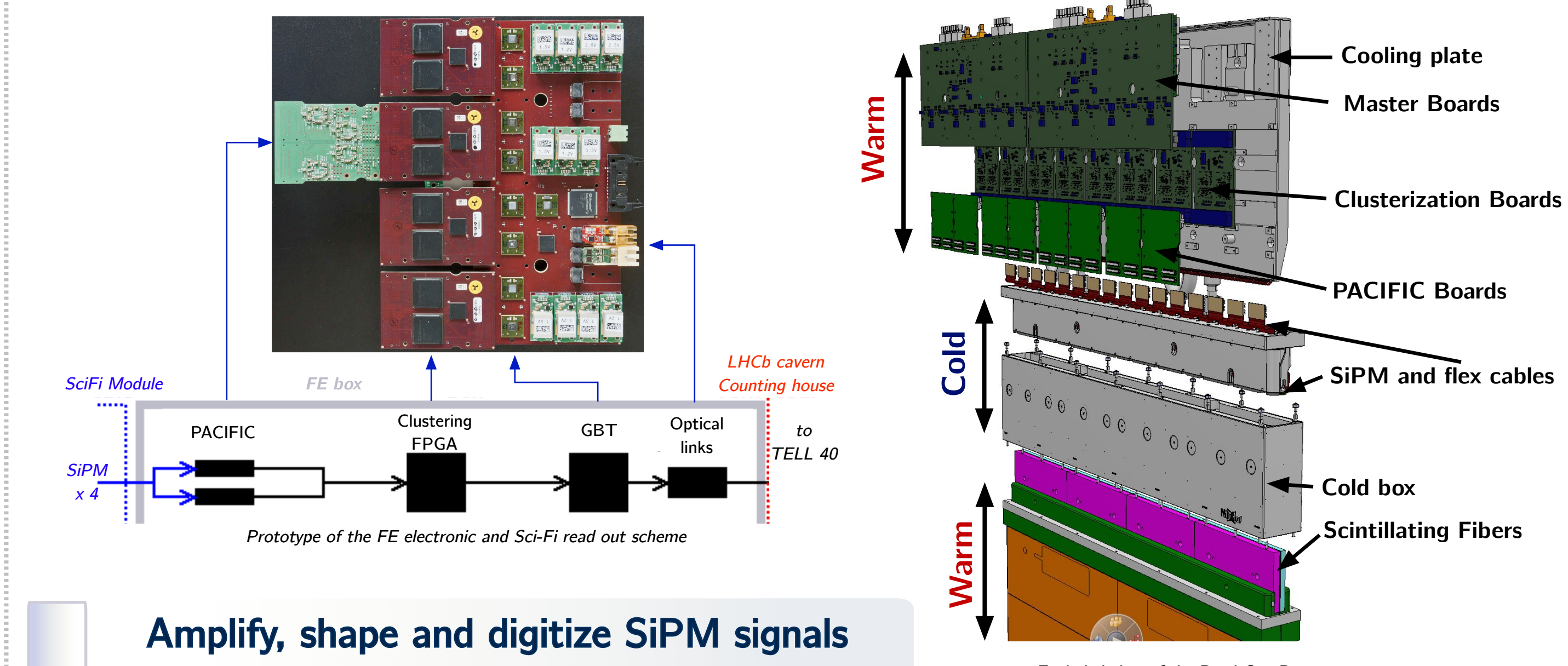


SiPM



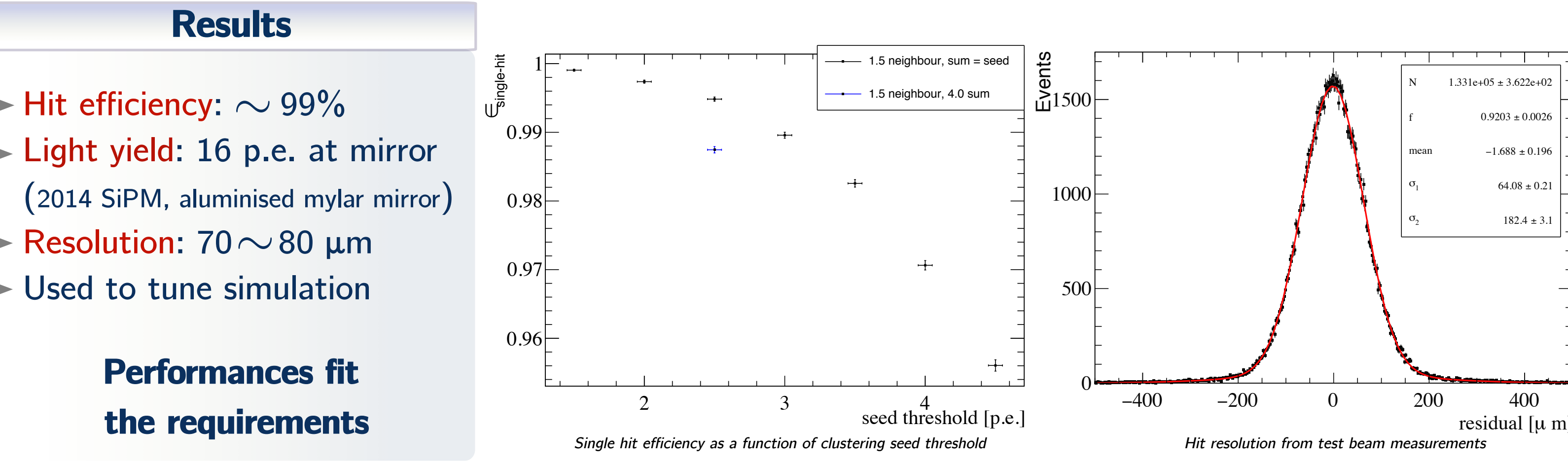
- SiPM for SciFi**
- Custom 128-channel SiPM Arrays
 - Fast signal response & short recovery time
 - Dark count rate (DCR) after irradiation (kHz \Rightarrow MHz):
 - Annealing @40°C: factor ~ 1.6 /week
 - Cooling: factor ~ 2 per 10°C
 - Operate SiPM at -40°C to reduce noise
- Key features**
- High PDE ($\Delta V, \lambda$)
 - Noise:
 - Dark count
 - Direct X-talk
 - Delayed X-talk
 - After-pulses
 - Radiation hardness: expected 1 MeV fluence up to $6 \times 10^{11} \text{ n}_{eq}/\text{cm}^2$
 - 2015 vs 2014 devices: higher PDE (50% vs 34%) but worse delayed X-talk.

SciFi Read-Out



- PACIFIC**
- Amplify, shape and digitize SiPM signals
 - Mixed-signal ASIC connected without interface to SiPM arrays:
 - Current input with 4 selectable gains
 - Tunable fast shaper to cut signal tail
 - Double gated integrator (no dead time)
 - Digitized with a 3-bit nonlinear flash ADC @40 MHz
 - Output sent to Clustering FPGA
- Read-out box**
- Cooling system in confined space**
- Front End electronics + cooling
 - SiPM at -40°C
 - Flushed with Nitrogen
 - Light & thermally insulated

TestBeam results



Summary

- The project is currently at the transition to fibre mat and module series production from four different centers after the successful EDR [3].
- Fibres production and delivery has started (150 km/week).
- SiPM production fulfill requirements, improvements expected.
- Full electronics read-out chain prototyped.
- SciFi planned to be installed starting from January 2019.