Qualification of irradiated FBK 3D pre-production pixel sensors for the ATLAS ITk detector

VERTEX 2023 – Sestri Levante

### 32nd International Workshop On Vertex Detectors

1. ATLAS ITk for HL-LHC

The **ATLAS ITk** → a new **all-silicon tracker** for the High Luminosity phase of LHC

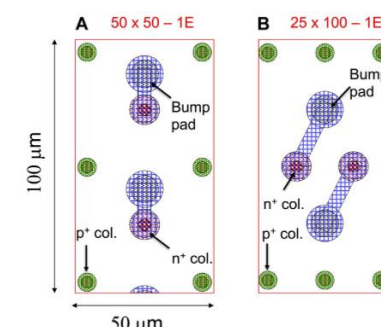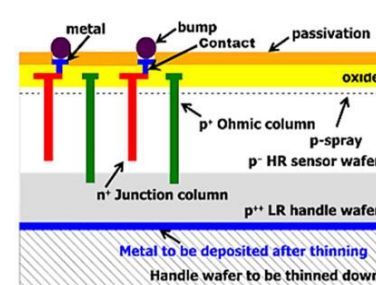**Strip sub-system** covering up to $|\eta| <$ 2.7 (4 Barrel layers + 6 disks)
Pixel sub-system covering up to $|\eta| <$ 4.0 (5 Barrel layers + rings)
- Planars in the outer layers
- **3D pixel sensors in the innermost layer produced by:**
  - Fondazione Bruno Kessler, FBK (I)
  - Stiftelsen for industriell og teknisk forskning, SINTEF (Nw)
  - Centro Nacional de Microelectrónica, CNM (E)
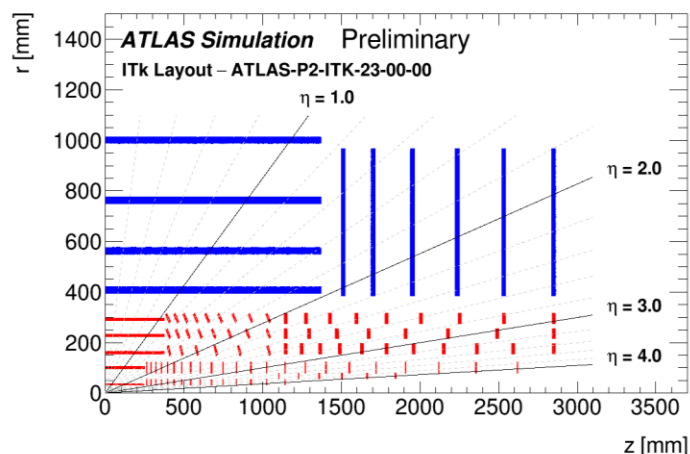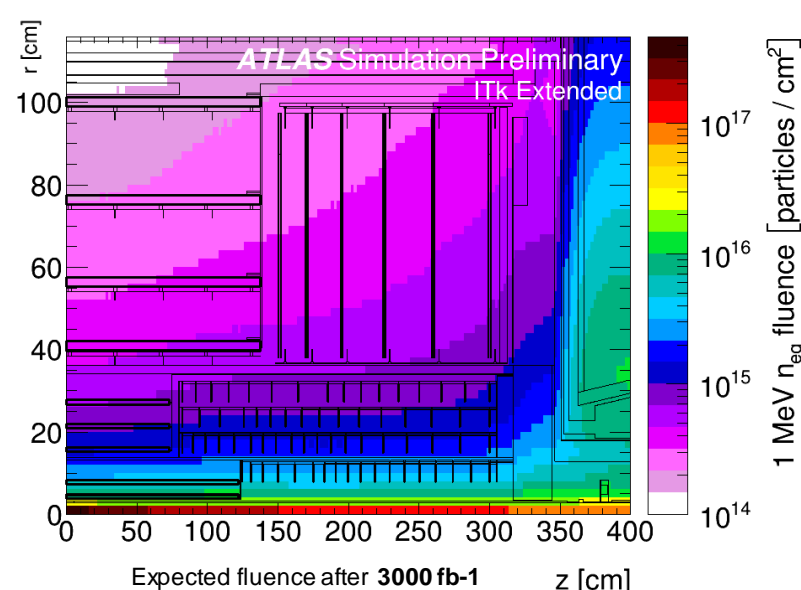
2. Pixel 3D sensors tecnology

Pros	**Cons**
Low depletion voltage	Uniform spatial response
Fast response rise	Higher capacitance respect
Less trapping probability	to planar
→ **RAD-HARDNESS**	**Cost, yield**

3D sensors pixel cell: 25x100 (um^2) - barrel / 50x50 (um^2) end-caps

3. ITk-Pixel expected fluence

Expected fluence after **3000 fb-1**

Inner System needs to be **replaced** at the half of HL program.

Including safety factor, the **Innermost layer** will reach up to
- **1 GRad TID**
- **1.9e16 n_{eq}/cm^2 - End-of-life Fluence (EOF)**

4. Performance at 1e16 n_{eq} / cm^2

- Several **TB campains**
- **Efficiency higher than 97%** with sensors inclined of 15° wrt beam axis
- Number of **disabled pixels** lower than **0.1 %**
- **50x50 reaches 97% at lower bias wrt 25x100** as expected

- **Irradiation** in Bonn (13 MeV protons) and KIT (23 MeV protons)
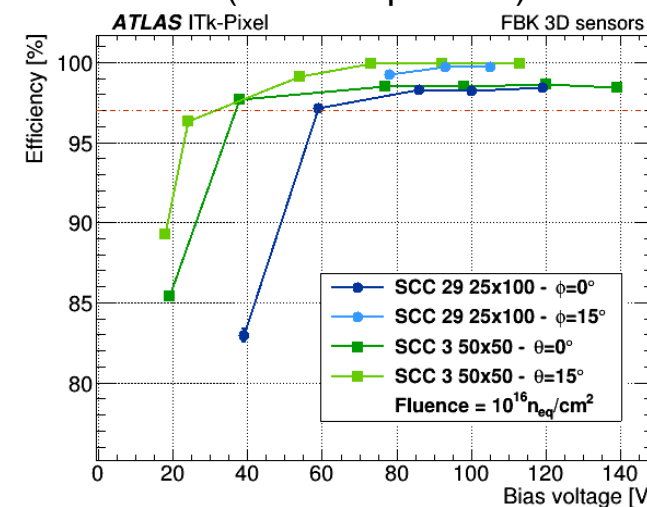
5. Performance and operation at EOF fluence – 1.9e16 n_{eq} / cm^2

3D sensors by **FBK with pitch 50x50 um^2** tested in 2022 & 2023

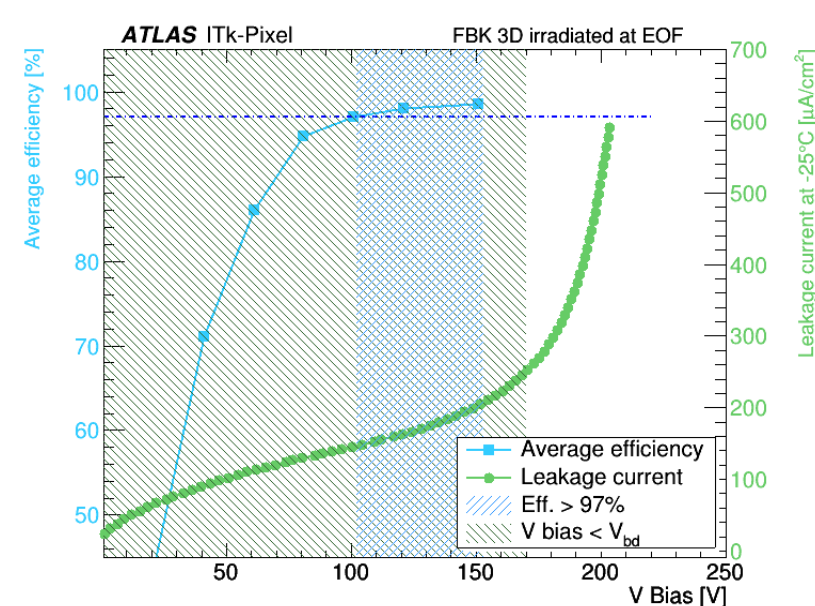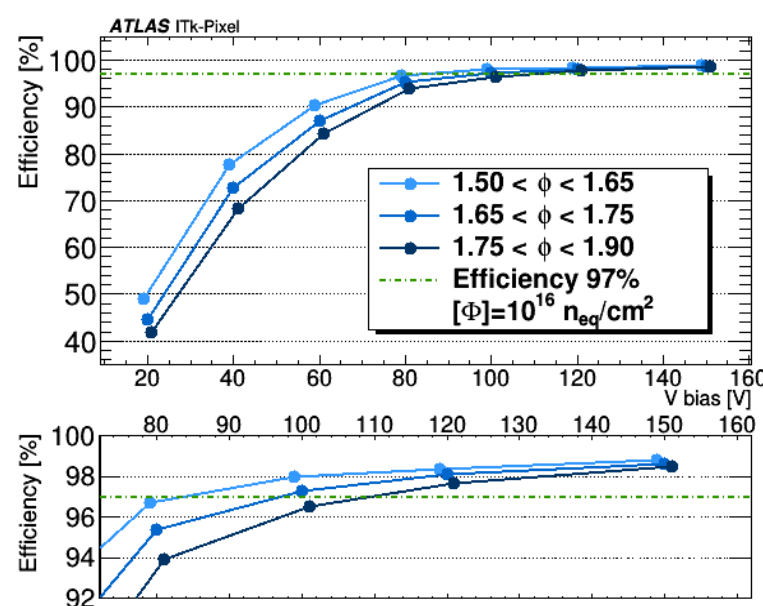**Irradiation at IRRAD facility at CERN**
- 23GeV proton beam
- Beam FWHM is 12x12 mm^2
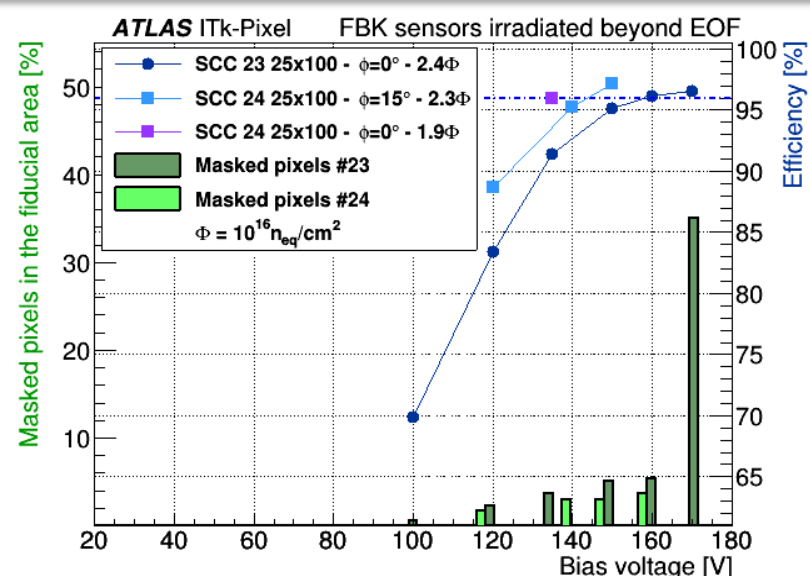- Devices scanned and tilted on the beam

Pixels are grouped in three ranges according to the reconstructed fluence received
- **Efficiency reaches 97% at 120-150V** depending on the fluence

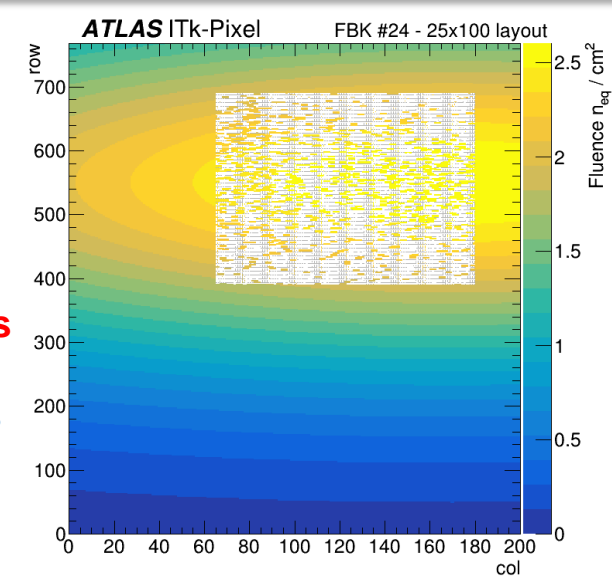The number of **masked pixel** is around **3% up to 130V** and then increases quickly

6. Studies beyond EOF – 2.5e16 n_{eq}/cm^2

FBK sensors with pitch 25x100 um^2 irradiated at IRRAD in 2023
- Test beam and dosimetry performed in parallel
- Mean fluence on the Al dosimeter is 1.7e16 n_{eq} / cm^2
- **Peaks up to 2.5e16 n_{eq} / cm^2**
- Performance are evaluated on a **fiducial area** using **only the enabled pixels**

Efficiency reaches 96% (normal incidence) even after irradiation at **2.5e16** although with the **5% of disabled pixels**
Efficiency is close to **97%** (inclined) in a fiducial area with mean fluence around **1.9e16** with the **3% of disabled pixels**
The **number of disabled pixels is more under control at slightly lower bias**, where it is expected to reach the required efficiency when the sensors are tilted.

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