The design and layout of the Phase-II upgrade of the Inner tracker (ITk) of the ATLAS experiment.

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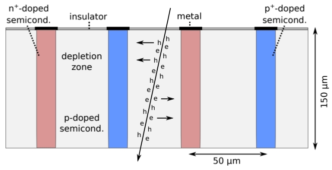
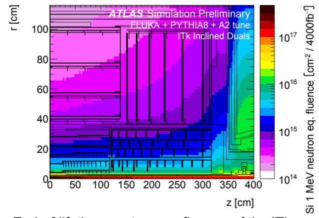
Pixel detector

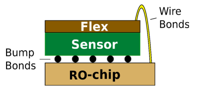
- **Sensors:**
  - 3D and planar sensors
  - Pixel sizes of 50x50 μm^2 and 25x100 μm^2 considered
- **RD53A read-out (RO) chip:**
  - 65 nm CMOS chip
  - ~150,000 channels
  - 4-bit ToT per pixel
  - Size: ~2x2 cm^2
- **Radiation hardness:**
  - High radiation dose requires replacement of two innermost pixel layers
  - Planar and 3D sensors remain efficient at end-of-lifetime irradiation
- **Serial powering:**
  - Reduces amount of cables significantly



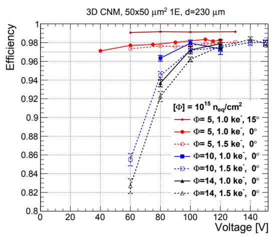
Sketch of a 3D pixel sensor



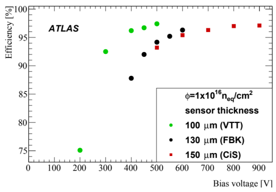
End-of-lifetime neutron eq. fluence of the ITk



Side view of an ITk pixel module



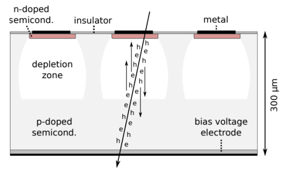
3D modules remain efficient after irradiation



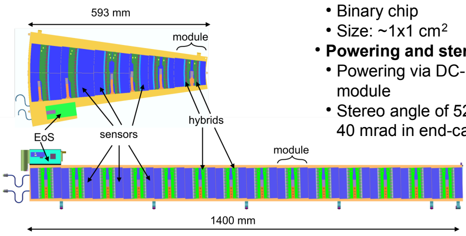
Planar signal remain efficient after irradiation

Strip detector

- **Sensors:**
  - Different sensor geometries in barrel and end-cap
  - Barrel strip pitch of 75.5 μm
- **ABCStar read-out chip:**
  - 130 nm CMOS chip
  - 256 read-out channels
  - Binary chip
  - Size: ~1x1 cm^2
- **Powering and stereo angle:**
  - Powering via DC-DC converter on module
  - Stereo angle of 52 mrad in barrel and 40 mrad in end-cap

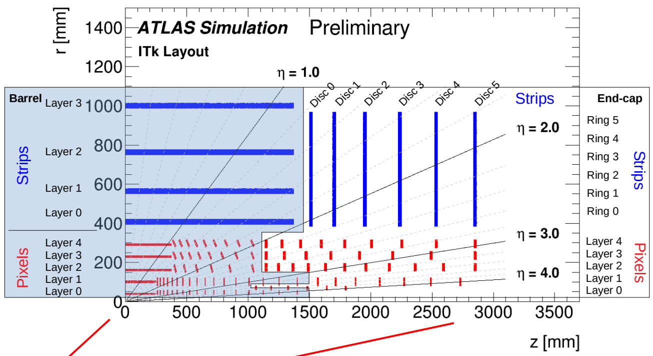


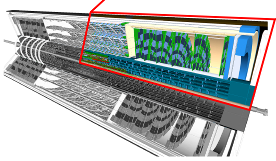
Sketch of an ITk strip sensor



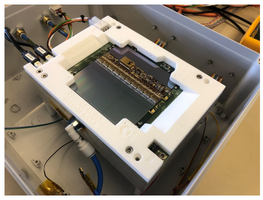
Mechanical elements of the strips end-cap (top) and barrel (bottom)

Current ITk layout

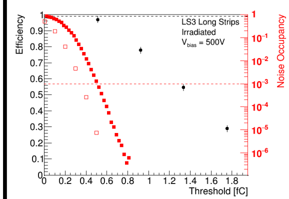




- **Design requirements for HL-LHC:**
  - Tracking at least as good as Run 2 ATLAS
  - Radiation levels of 2–3 x 10^{16} n$_{eq}$/cm^2 for pixels and 10^{15} n$_{eq}$/cm^2 for strips
  - Hit density of up to 0.643 hits/mm^2 for pixels and 0.005 hits/mm^2 for strips
  - Trigger rate of 1 – 4 MHz



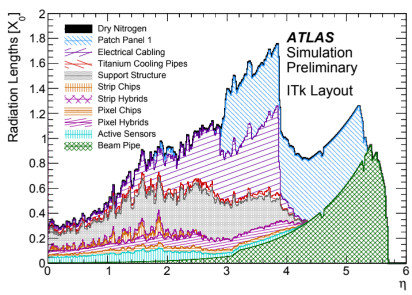
Picture of a barrel module of the two outermost layers



Strip barrel signal efficiency and noise occupancy after end-of-lifetime irradiation

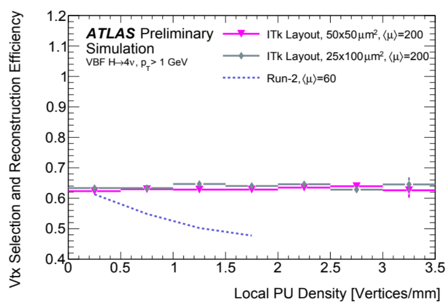
Expected performance

- **Material budget**:
  - Less than two radiation lengths (Run 2 up to six)
  - Cabling and support structure significantly reduced w.r.t. LHC Run 2



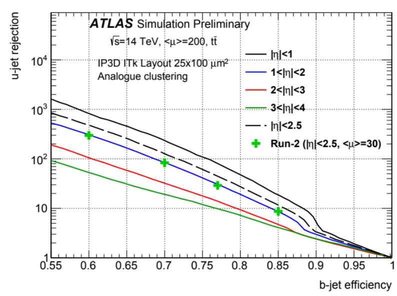
Material budget of the ITk in electromagnetic radiation lengths

- **Vertex selection and reconstruction efficiency**:
  - Shown for VBF $H\rightarrow 4\nu$ events (tracking in forward jets)
  - Employ new vertex reco algorithm (Adaptive Multi-Vertex Finder)
  - Vertex selection according to highest $\Sigma\, p_T^{\,2}$, not fulfilled by 20% of VBF $H\rightarrow 4\nu$ events



Vertex sel. & reco. efficiency is constant versus pile-up density

- **b-tagging light-jet rejection:**
  - Higher d$_0$-accuracy of 25x100 μm^2 pixels yields more light jet rejection
  - Improvement of capabilities w.r.t. LHC Run 2 (compare black dashed line and green crosses)



The ITk light-jet rejection (----) is comparable to LHC Run 2 (+)

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References:
[1] CERN-LHCC-2017-005
[2] CERN-LHCC-2017-021
[3] ATL-PHYS-PUB-2019-014

ATLAS EXPERIMENT