Mighty Tracker: HV-MAPS @ LHCb UII

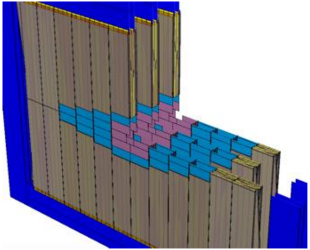
José Mazorra de Cos

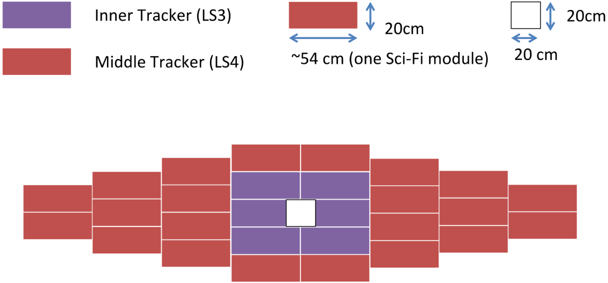
Instituto de Física Corpuscular (CSIC-UV)

PixLab Meeting - 4th May 2020

Mighty Tracker

- Proposed LHCb upstream tracker after Upgrade II.
- Silicon sensors counteract SciFi limitations in terms of radiation damage and maximum occupancy.
- Time measurement not expected to be required.
- Readout and services integrated in SciFi module.

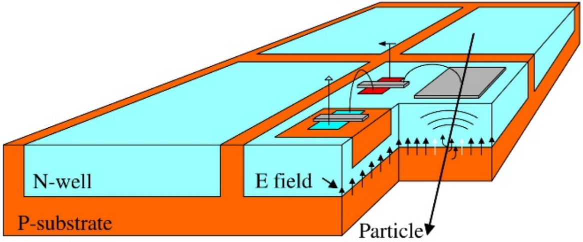




- Cover 18(4)m^2 after LS4(3).
- Only 6 layers required.
- MT receives ~50% tracks.
- Up to 415 Gbps per layer.
- Maximum expected fluence 3x10^{14} 1 MeV neq/cm^2.

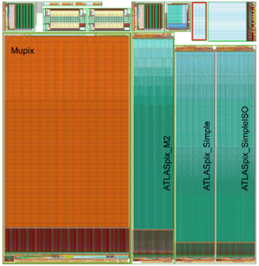
Silicon Sensors

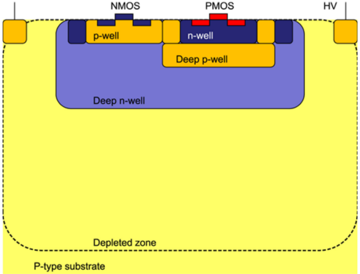
- Initially silicon strips sensors were also contemplated but HV-DMAPS pixel sensors were always the baseline option.
- Several technologies of HV-MAPS were originally studied:
  - collaboration has experience and mature solutions with AMS/TSI 180nm,
  - solutions with Lfoundries 150nm are also suitable but not so advanced,
  - TowerJazz improves power consumption but unknown radiation tolerance.
- Latest version of MuPix/ATLASPix used as reference for specifications.



HV-MAPS Technology

- The design will be developed in TSI 180nm technology, allowing synergy (dsgn&mfg) with MuPix/ATLASPix.
- Chip area (~2cmx2cm) limited by TSI reticle size.
- Aiming at large fill factor device with <5% dead area (guardring + dicing 100µm, but dominated by periphery).

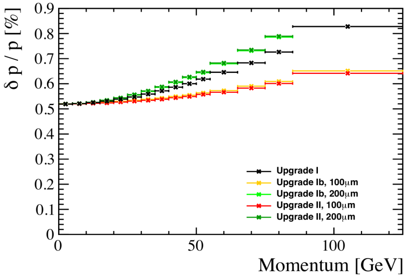


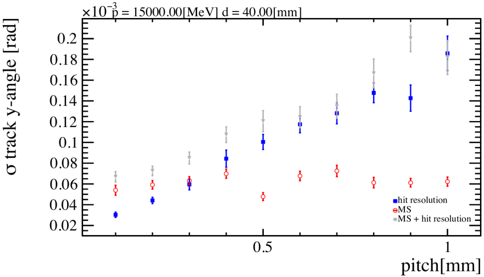


- TSI HV process layer map includes triple well, which offers additional design options.
- TSI HV process offers high resistivity wafers, which enlarges depletion region.

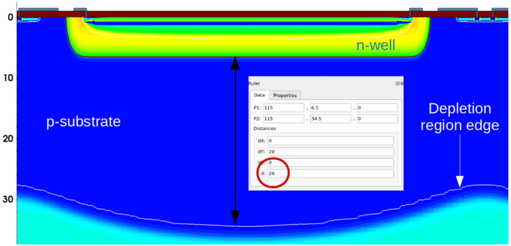
HV-MAPS Pixel Size

- Baseline size 100μmx300μm considering down to 50μmx150μm.
  - Horizontally 100μm assures LHCb UI momentum resolution.
  - Vertically, under 300μm multiple scattering dominates resolution over pixel size.
- Baseline can increases capacitance a factor 2 with respect to current devices taking a big toll on power consumption and/or time-walk dispersion.
- Smaller pixel size with logical sum included in readout is also considered.





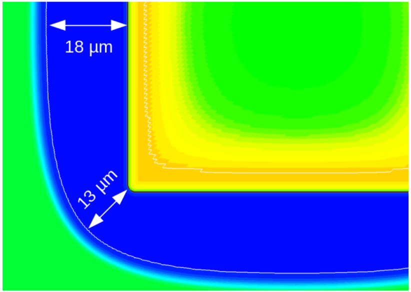
HV-MAPS Pixel Size



P1: 115 . 6.5 . 0
P2: 115 . 34.5 . 0
dX: 0
dY: 28
dZ: 0
d: 28

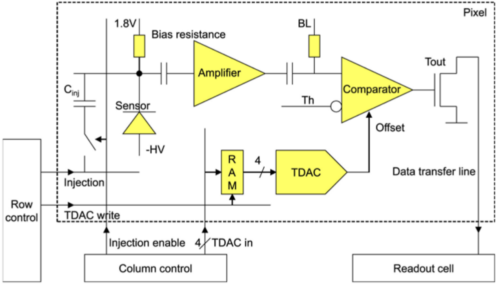
- Sensor thickness set at 200μm, analogue by size to ATLASPix (50μmx150μmx250μm).
- TCAD yields ~30μm depletion region for 60V bias and 200Ωcm wafer.

- Charge deposit in 4μm radius cylinder.
- Geometrically 98% of single cell clusters, other effects still have to be considered. (delta-rays, cross-coupling ...)
- Further studies in lateral growth and corners to assure full depletion in whole matrix.



HV-MAPS Readout

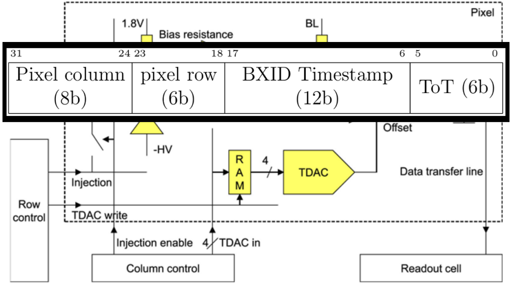
- Pixel would include bias resistor, amplifier and comparator (no design yet).
- Voltage (source follower) and current (current driver) amplifiers available, also nMOS exclusive and CMOS comparators (in-pixel and periphery).
- Radiation tolerance enhanced by enclosed transistor and low drift length.



- Hit efficiency $>$99%
- Noise $<$30Hz/px (1% avg data rate)
- Power $<$150mW/cm^2
- Time resolution $<$3ns (4σ in 25ns)
- Total ionizing dose $<$40MRad
- N fluence $<6\text{x}10^{14}$ 1 MeV neq/cm^2
- Output data rate 4x1.28Gbps

HV-MAPS Readout

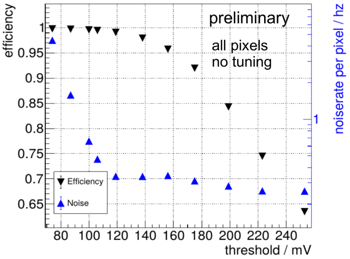
- Continuous readout with timestamp per hit to avoid on-chip descramble, ToT for time walk correction and 8b10b encoding for DC-balance.
- Assuming 1.7 events per chips, maximum data rate below 2.5Gbps.
- Optical interface through lpGBT with experiment readout and control systems.



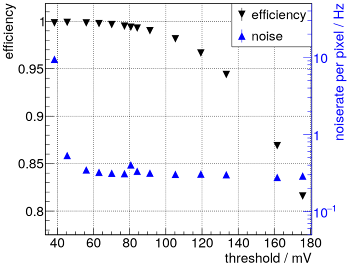
- Hit efficiency >99%
- Noise <30Hz/px (1% avg data rate)
- Power <150mW/cm^2
- Time resolution <3ns (4σ in 25ns)
- Total ionizing dose <40MRad
- N fluence <6x10^{14} 1 MeV neq/cm^2
- Output data rate 4x1.28Gbps

MuPix/ATLASPix Performance

- High efficiency and low noise overlap in all devices.
- Migration to TSI successful.
- Wafer resistivity effect apparent.

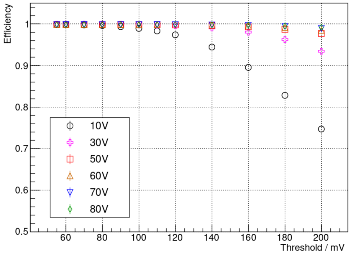


ATLASPix3
TSI 180nm
80Ωcm??



MuPix8
AMS 180nm
80Ωcm

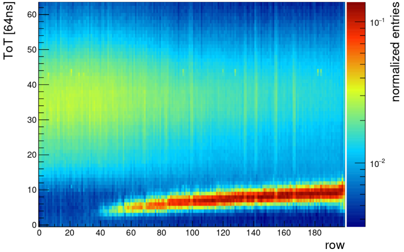
ATLASPix1
AMS 180nm
200Ωcm

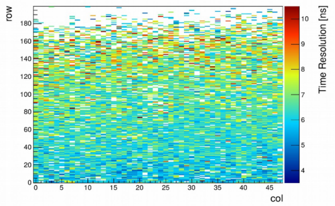


MuPix/ATLASPix Performance

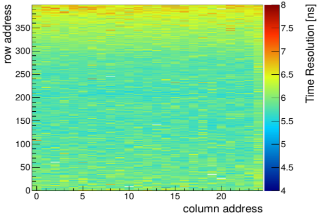
- Time resolution ~6ns in all devices after time walk correction with ToT.
- MuPix8 uses periphery comparators, cross-coupling affects ToT measurement.
- ATLASPix1 intrinsic resolution below 4ns.

MuPix8 AMS 180nm 80Ωcm

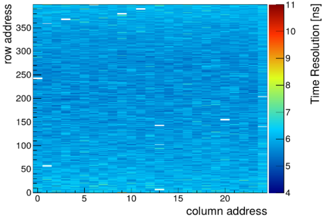




MuPix8



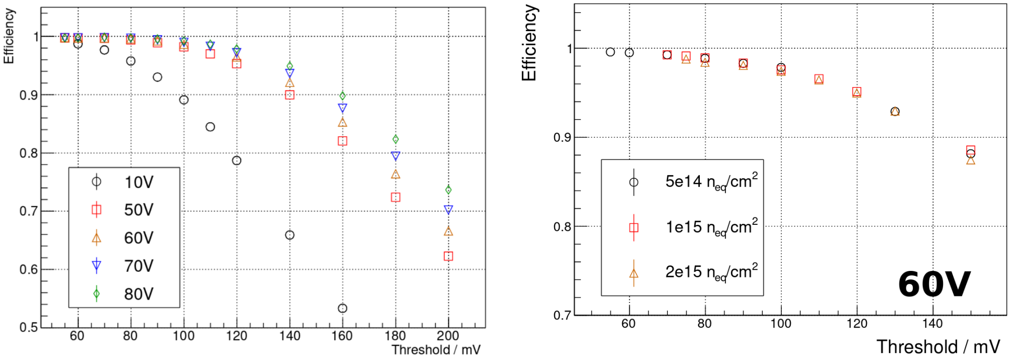
ATLASpix_simple



ATLASpix_simple_iso

MuPix/ATLASPix Performance

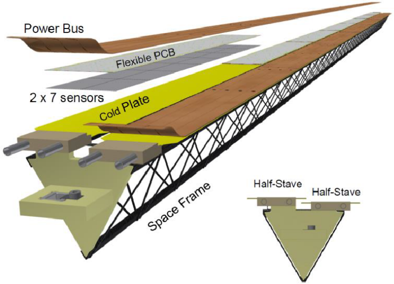
- ATLASPix radiation tolerant at higher fluence than required.

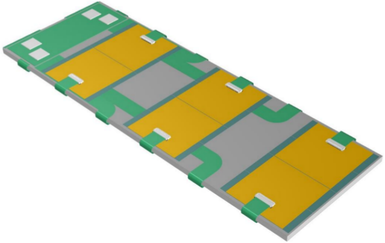


ATLASPix1 AMS 180nm 80Ωcm

Module & Services

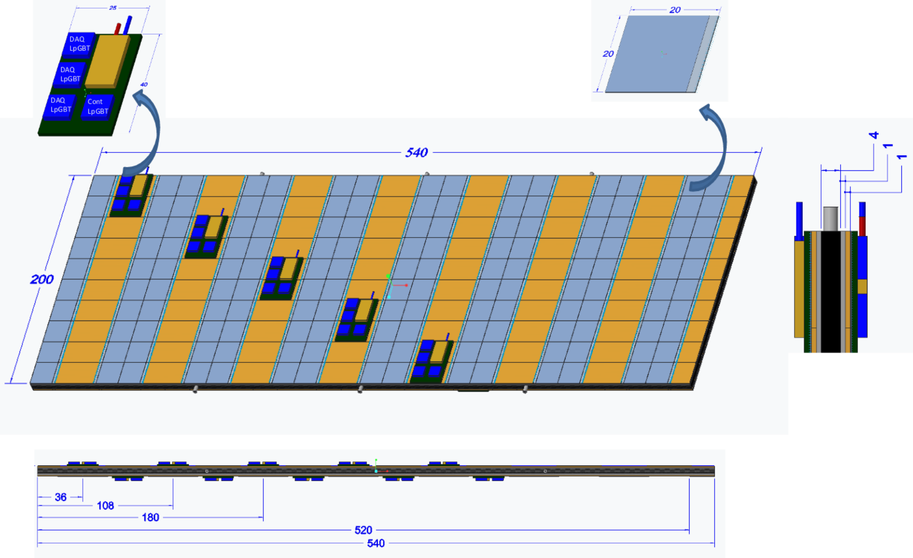
- Design inspired in ATLAS ITk and ALICE inner tracker.
- Light carbon fiber structure for sensor and cooling system.
- Structure embeded in SciFi module, alternative for empty layers required.





- Service access planned vertically integrated or on top of SciFi module.
- Cooling 200W per module with ~15°C water extrapolating from ATLAS ITk ~3l/min.
- First DAQ estimations yield 200 fibers.

Module & Services



Thanks a lot for your attention!