Sensor concepts for future hybrid pixel detectors

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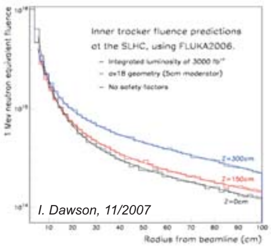
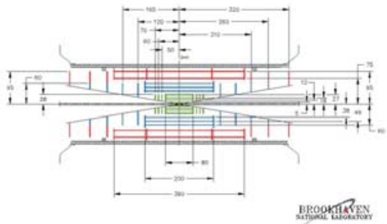
sLHC - Requirements: ATLAS



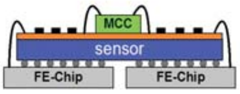
I. Dawson, 11/2007

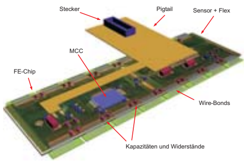


- Luminosity upgrade by a factor of 10 to 10^{35} cm^{-2}s^{-1}.
- Occupancy increases by 20 -> 5-10 kTracks/event.
- Pixel layers at R=40, 80, 160 and 200 mm.
- Resulting fluencies after 3000 fb^{-1} (5 years):

up to $2.0\cdot10^{16} n_{eq}$ cm^{-2} for R= 37 m & $1.0\cdot10^{15} n_{eq}$ cm^{-2} for R= 200mm.

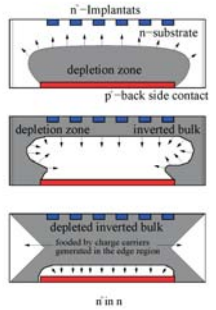
ATLAS Pixel module: FE-I3 & n$^+$-on-n sensor



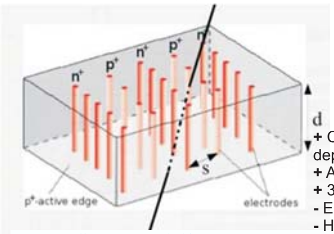


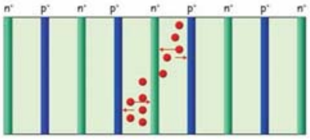
Module:
- Hybrid pixel detector.
- 16 FE chips & 1 sensor.

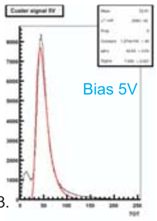
Sensor:
- DOFZ silicon, n-type.
- n$^+$-on-n sensor.
- Double sided process.
- Moderated p-spray isolation.
- Underdepleted operation after type inversion.
- radiation tolerant up to $1.0\cdot10^{15} n_{eq}$ cm^{-2}.



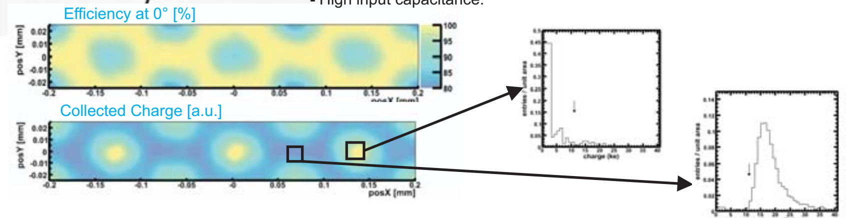
3D-Active-Edge-Sensors



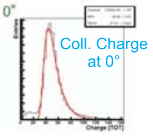


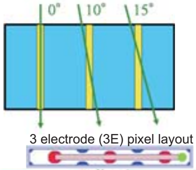


- \+ Charge collection lateral to charge generation -> low depletion voltages & better CCE after irradiation.
- \+ Active edges possible.
- \+ 3D sensor with ATLAS pattern bump bonded to FE-I3.
- \- Electrode structure induces inhomogeneities.
- \- High input capacitance.

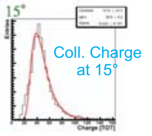


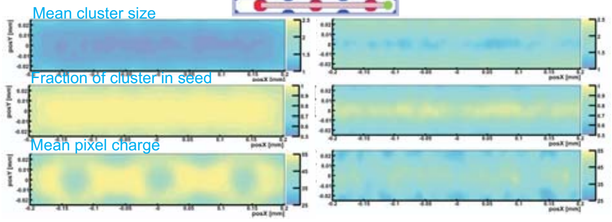
3D Sensors Testbeam Results





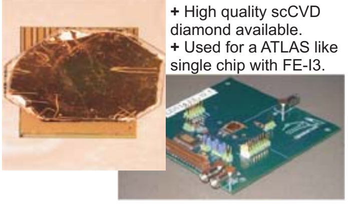
3 electrode (3E) pixel layout



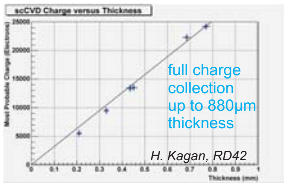


- Insufficient charge collection in the electrodes leads to inefficiencies for vertical tracks.
- For tilted tracks the charge collection inefficiencies average out -> 99.9% efficiency.

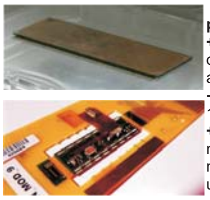
Diamond Sensors



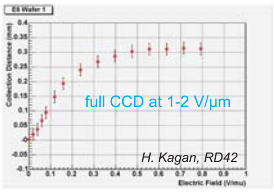
scCVD diamond:
- \+ High quality scCVD diamond available.
- \+ Used for a ATLAS like single chip with FE-I3.



H. Kagan, RD42



pCVD diamond:
- \+ Improved quality of wafers > 12cm available.
- \- Mean charge 11300e$^-$.
- \+ 1 full ATLAS module built & 2 more are currently under assembly.



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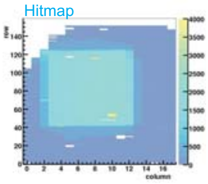
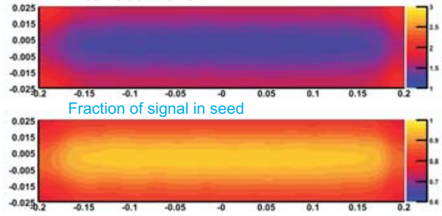
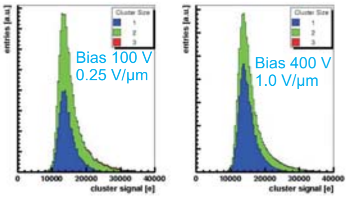
scCVD diamond testbeam results

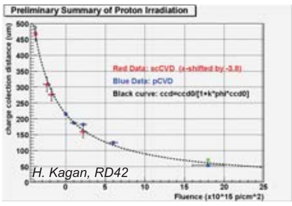


- High class bump connectivity.
- In pixel measurements show no visible inhomogeneities.
- full charge collection down to E=0.25V/µm.
- carrier drift velocity & cluster size adjustable by electric field.





Radiation tolerance:
- pCVD and scCVD up to $1.8\cdot10^{16}$ pcm^{-2} at E=1V/µm & E=2V/µm resp.
- pCVD & scCVD follow same damage curve: 1/ccd=1/ccd0 + k·φ but with an offset.



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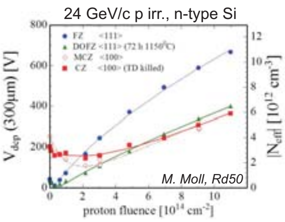
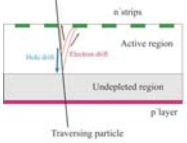
Planar Silicon Sensors

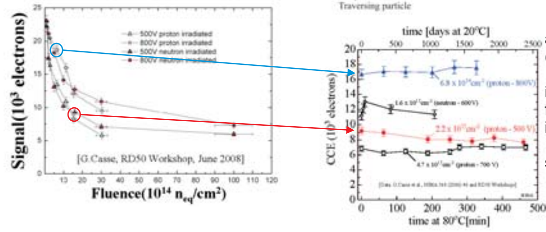


M. Moll, Rd50

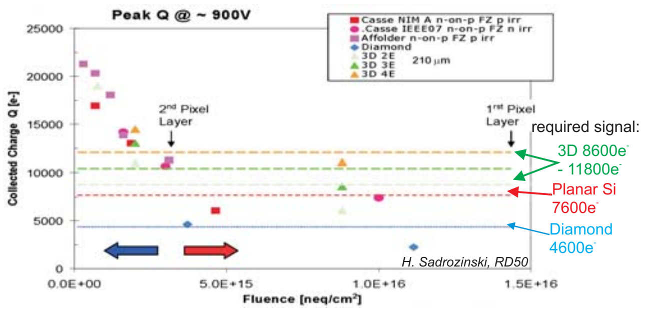
Strong differences in V_{dep} for the different materials:
- Type inversion for n-FZ, n-DOFZ, no type inversion for n-MCZ, p-type Silicon do not invert (acceptor generation).
- Sensitive to particle flavor (p,n, pions), thin EPI materials.
- More complex effects (double junction etc.).
- Common to all materials is the increase in reverse current & trapping for holes and electrons reducing the CCE (~20%).



n$^+$-on-p (FZ/MCZ):
- Junctions remains on readout side after irradiation (like n$^+$-on-n).
- Electron collection.
- ~30% CCE (7300e$^-$) after 10^{16} cm^{-2} at 800V (strip detectors).
- No reverse annealing in CCE measurements for neutron and proton irradiated detectors!
- Cost reduction due to single sided process (?).



Conclusions



required signal:
3D 8600e$^-$ - 11800e$^-$
Planar Si 7600e$^-$
Diamond 4600e$^-$

H. Sadrozinski, RD50

Comparison of expected with required charge for different sensors:
- Required minimal signal for different sensors = 2 times in-time-threshold.
- Differences due to the noise/capacitance behavior of the sensors.
- Planar n-on-p sensors adequate for all but innermost pixel layers.
- Innermost pixel layer(s) at $>1.4\cdot10^{16} n_{eq}$ cm^{-2} with marginal performance.

Need improved sensors or improved FE electronics!