HPK ATLAS12A Endcap Mini Sensors
Electrical Testing

Marcela Mikeštíková[1],
Víctor Benítez[2], Susanne Kuehn[3], Urmila Soldevila[4]

[1]Institute of Physics (Prague), [2]CNM (Barcelona), [3]Physikalisches Institute (Freiburg), [4]IFIC (Valencia)

Tested sensors

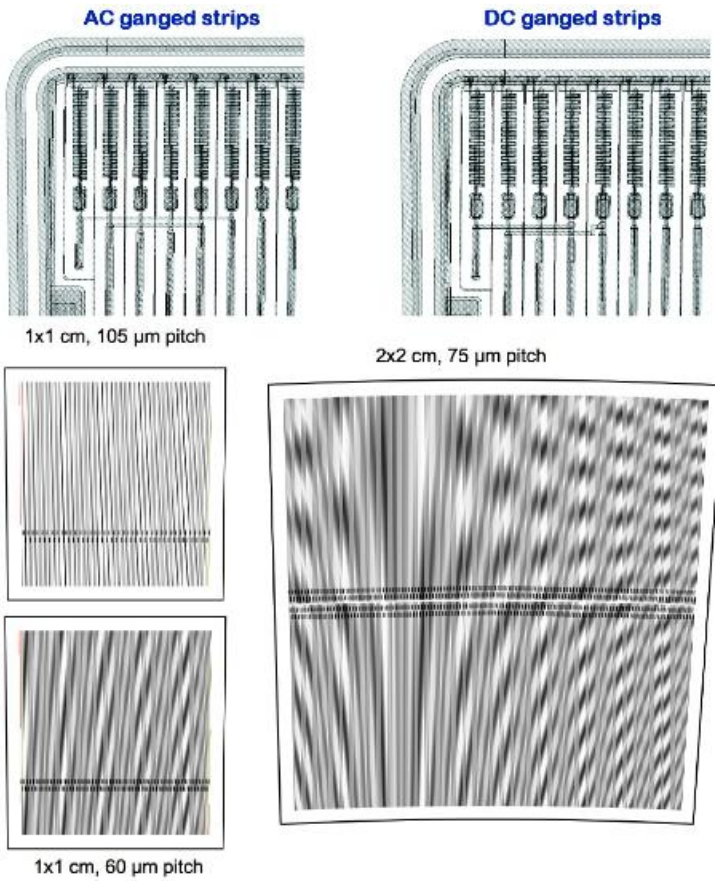
ATLAS12A EndCap mini sensors manufactured by Hamamatsu Photonics (HPK)
***n*-strip in *p*-type material (FZ)**

10 different types of EC mini sensors at each participating institute:

EC-small pitch-C (AC gang) #P7
EC-small pitch-E (AC gang) #P8
EC-large pitch-C (AC gang) #P9
EC-large pitch-E (AC gang) #P10
EC-small pitch-C (DC gang) #P17
EC-small pitch-E (DC gang) #P18
EC-large pitch-C (DC gang) #P19
EC-large pitch-E (DC gang) #P20
EC-skewed-C #P01
EC-skewed-E #P02

3 barrel mini sensors for comparision (PRG):

BZ3C #P2,4,12 W619



Status of endcap mini sensors I

Distribution and irradiation of EC mini sensors:

Unirradiated sensors (measurements done):

-10 unirradiated sensors at each participating institute Prague, Valencia and Freiburg for testing.
Results of testing are presented in this talk

Irradiatiated sensors (will be tested soon):

- 60 sensors were irradiated in Birmingham with protons:
3 fluences (2 sensors of each type): 5E14, 1E15, 2E15 Neq/cm2
Sensors will be distributed to Prague, Valencia, Freiburg for testing

- 30 were sent for gamma irradiation to BNL: proposed doses: 1MRad, 3MRad, 10MRad
with 2 sensors per dose. Only sensors with ganging and small pitch (#7,#8,#17,#18,#21)

-12 sensors were sent to Karlsruhe Synchrotron for irradiation with protons for comparison
to irradiation in Birmingham:
3 fluences (1 sensors of type #7,#8,#17,#18): 5E14, 1E15, 2E15 Neq/cm2

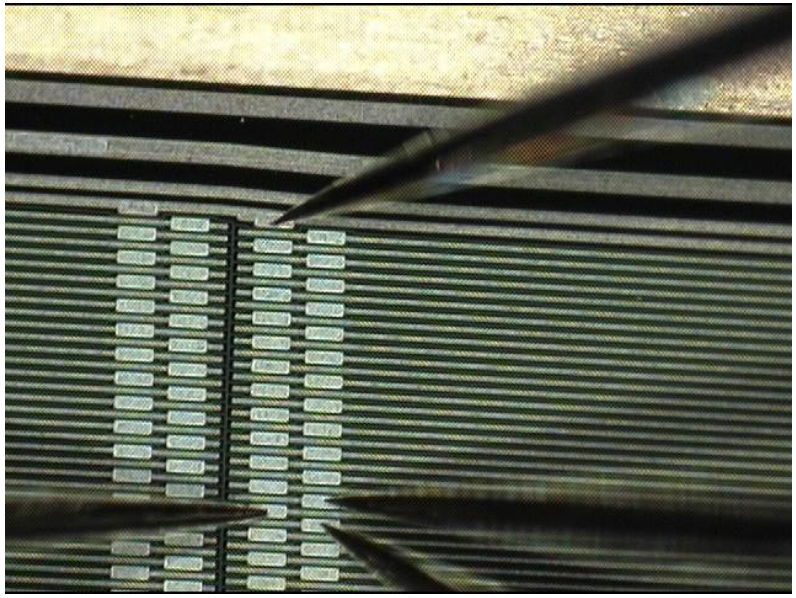
Electrical properties

Measurements done up to now:

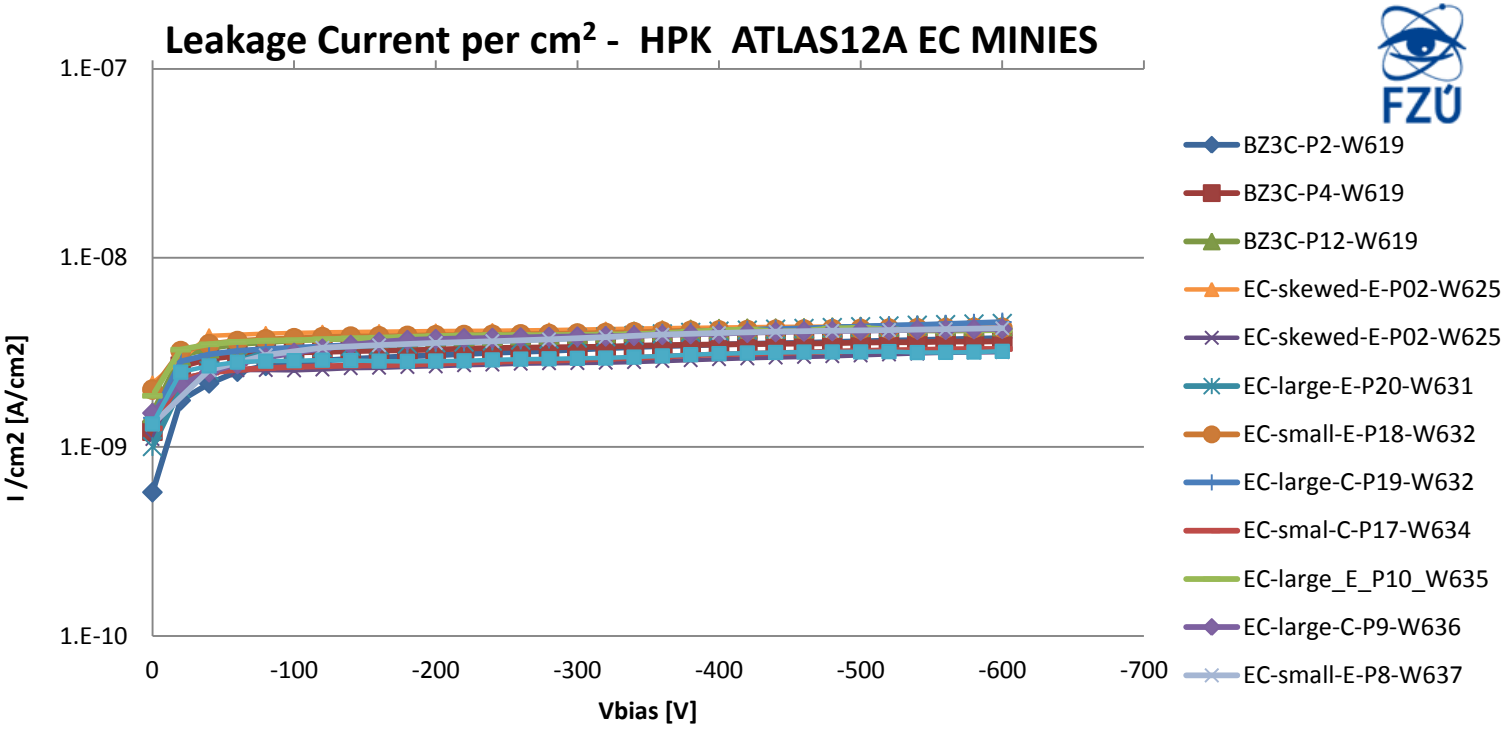
Non-irradiated sensors

- IV, CV characteristics, determination of Full Depletion Voltage
- Ccpl: AC Coupling Capacitance
- Rbias: Polysilicon Bias Resistance
- Cint: Interstrip Capacitance
- Rint: Interstrip Resistance
- PTP: Punch-through Protection

Comparison to specifications between ATLAS and HPK



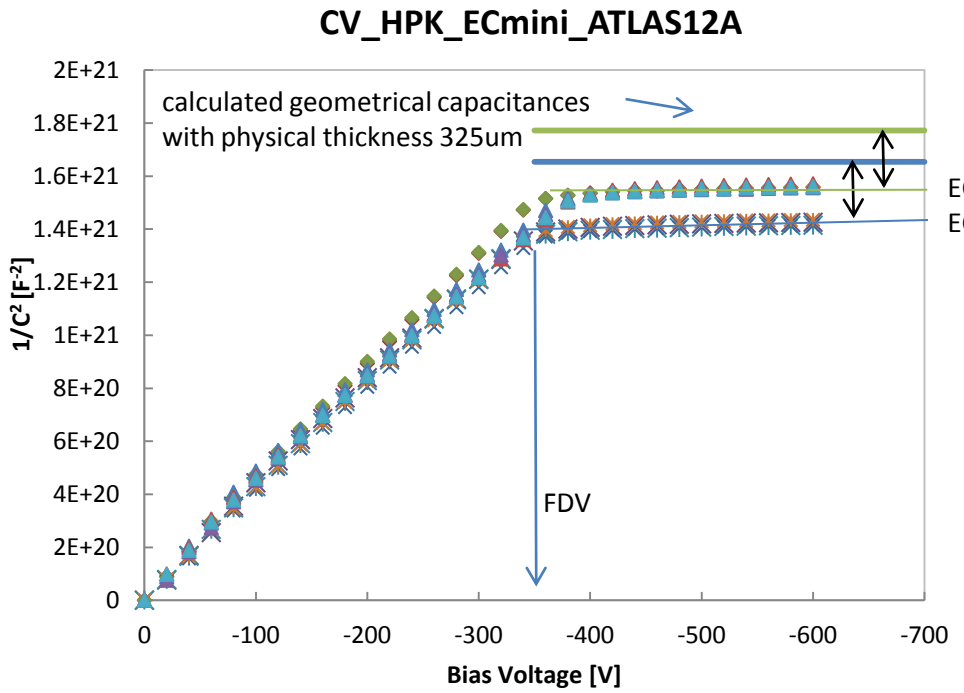
Leakage Current (IV)



- **No breakdown observed up to 600 V/1000 V sensor bias.**
- **Current @ 600 V (Prague and Freiburg):**
  - **4.2 ± 0.3 nA/cm² EC**
  - **3.4 ± 0.7 nA/cm² EC (skewed)**
  - **3.8 ± 0.1 nA/cm² Barrel**
  - **6.9 ± 0.8 nA/cm² EC (Valencia)**

Active areas used: EC mini: 0.69 cm2
EC skewed: 3.1 cm2
Barrel mini: 0.637 cm2

Full Depletion Voltage



EC large pitch
EC small pitch
different active area

- **Bulk Capacitance**

  The discrepancy between measured and calculated geometrical capacitance is due to the depth of the deep-diffused ohmic contact in the back

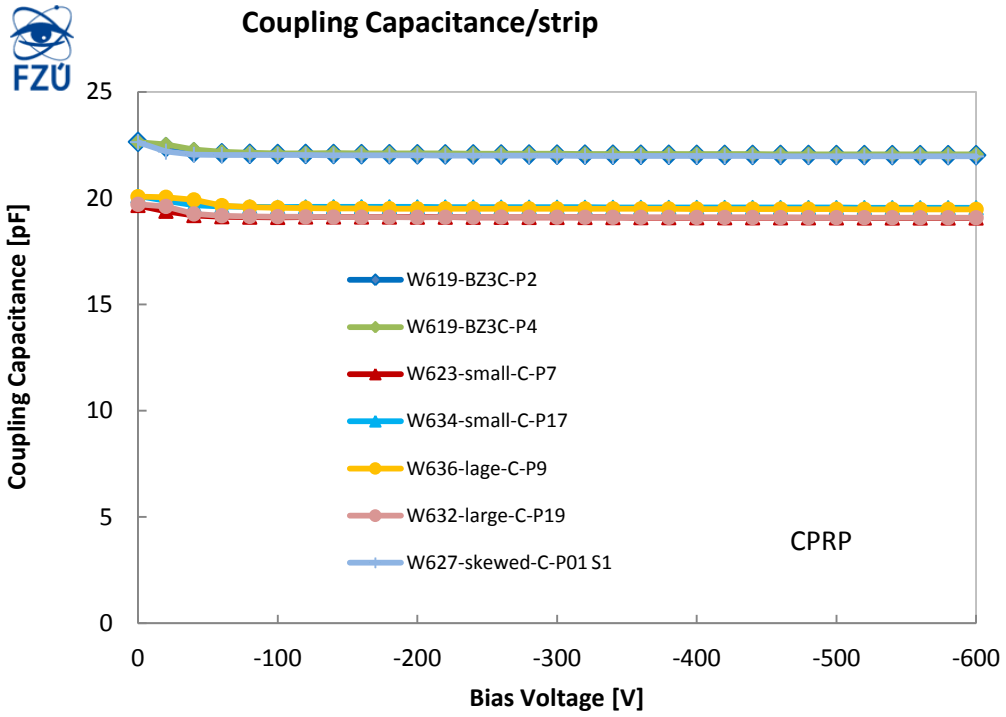
- **Resistivity: ρ = 2.8 ± 0.15 kΩ*cm**

  calculated from Full Depletion Voltage:

  $\rho = d^2/(2\varepsilon*\mu*V_{FD})$, **d = 302 µm** (active thickness)

- **Estimated values of FDV:**
  - **Freiburg 330.5 ± 7.3 V**
  - **Prague 361.8 ± 15.6 V**
  - **Valencia 363.3 ± 18.4 V**

Coupling Capacitance/ Polysilicon Bias Resistance



Measuring method:

C_{cpl} measured between strip metal (AC pad) and strip implant (DC pad) at 1kHz with CR in parallel

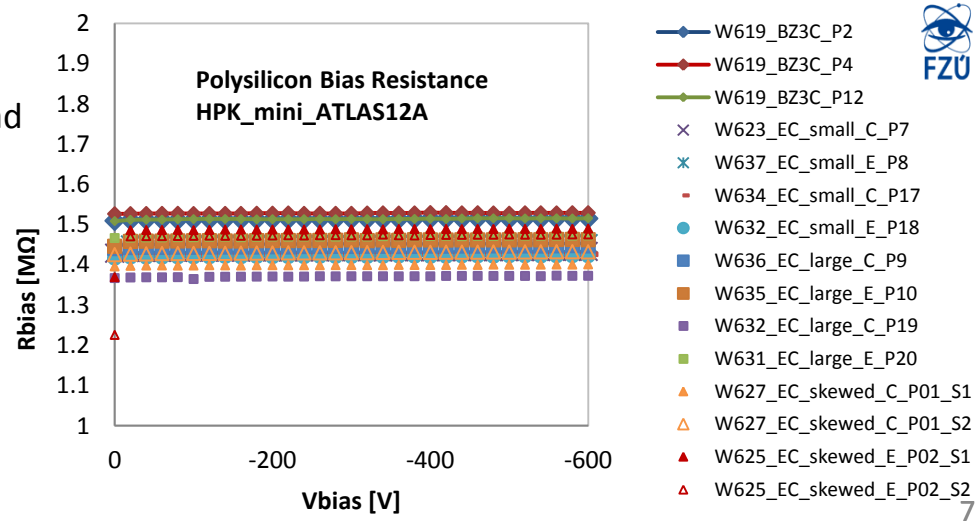
- **Summary Prague and Freiburg:**
  - **23.9 ± 0.7 pF/cm EC**
  - **25.0 ± 0.1pF/cm EC(skewed)**
  - **27.4 ± 0.03pF/cm Barrel**
- **Strip Ccpl agrees with Spec.**

Strip length used: EC mini: 0.806 cm,
EC skewed: 0.879 cm
Barrel mini: 0.805 cm

Rbias measuring method:

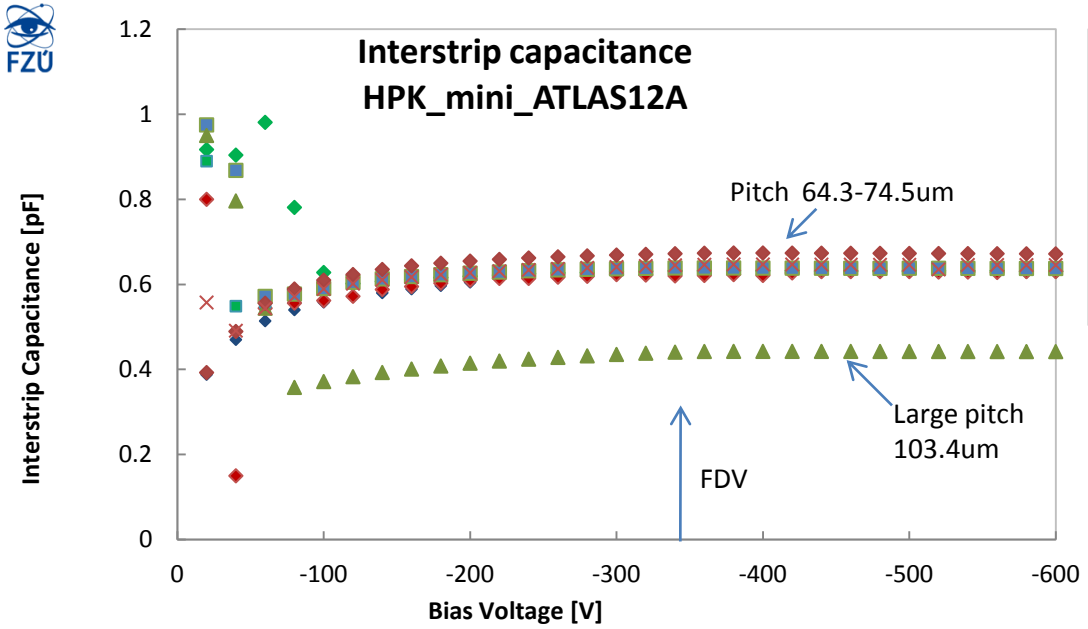
- IV scan made by SMU up to 5V applied to DC pad
- *Rbias=dVapp/dI*
- Rbias is constant with bias voltage

Rbias = 1.45 ± 0.04 MΩ

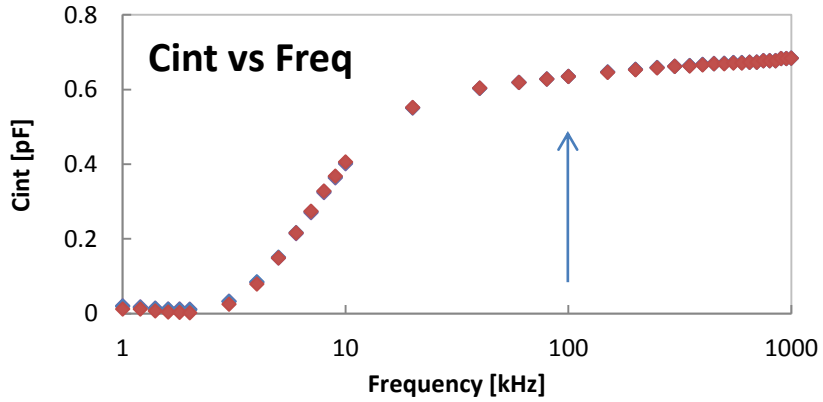


Inter-Strip Capacitance

- Measurements taken between the central strip and its neighbours on both sides – 3 probe method
- Cint measured on randomly selected strips in the middle of the sensor (not ganged strips)



- Variable behavior at low bias may be due to effects near surface during depletion.



	Average pitch [µm]	C_{int}/cm [pF]
Barrel mini	74.5	0.78
EC Small pitch	64.3	0.79±0.003
EC Large pitch	103.4	0.55±0.007
EC Skewed	69.4 S2 66.1 S1	0.74±0.003 0.76±0.004

All tested sensors meet the Tech. Spec.

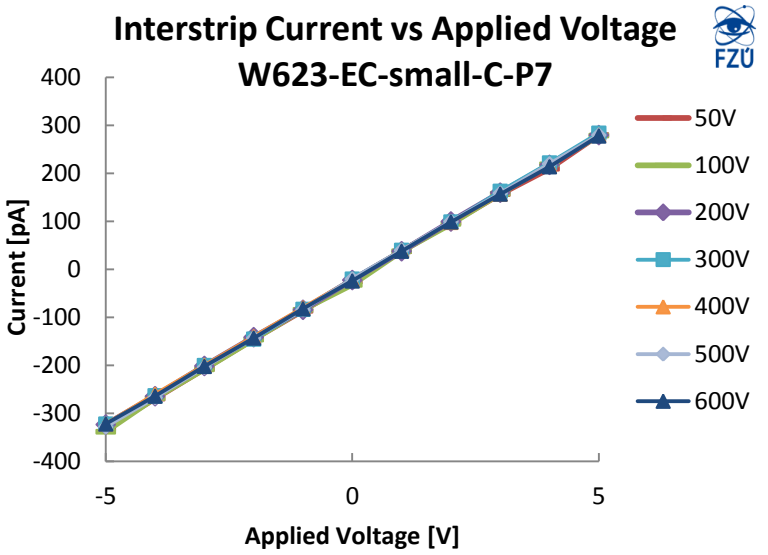
Inter-Strip Resistance

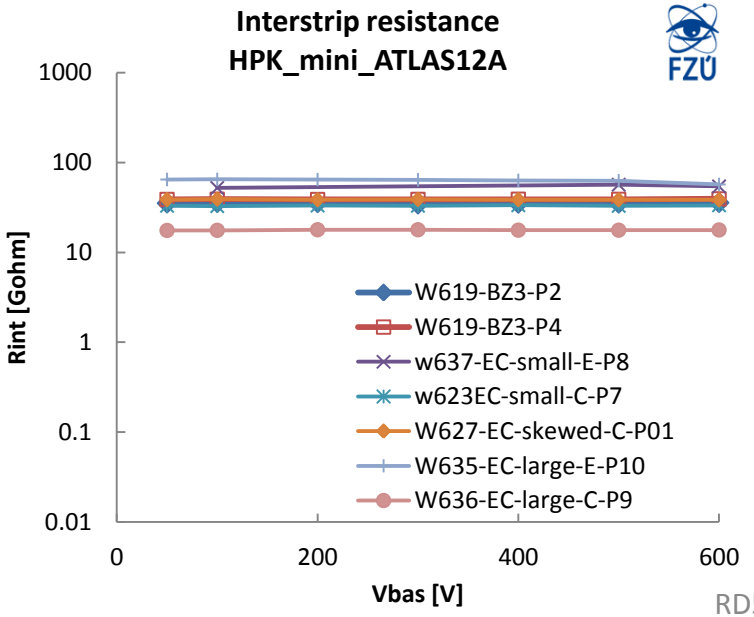
Measuring method:

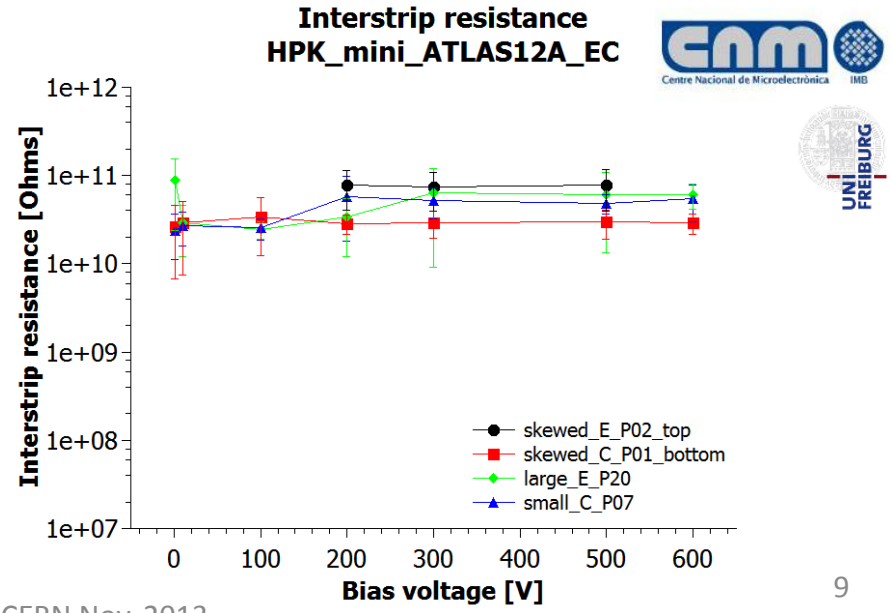
- Interstrip resistance measured by induced current method.
- 3 adjacent DC pads are contacted with 3 needles. On the outer strips is applied voltage V_{appl} by SMU, the current is measured on the central DC strip.

$$R_{int} = 2/(dI/dV_{appl})$$

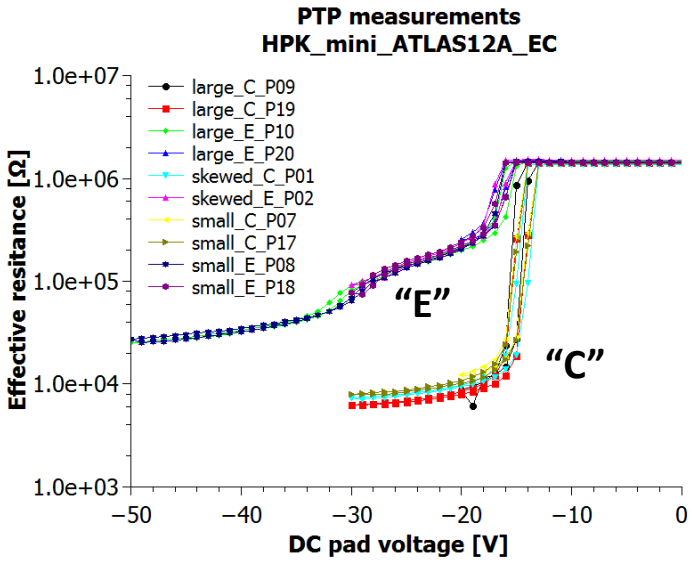
Summary from Prague and Freiburg:
- **Interstrip resistance Rint/strip = 18-78 GΩ**
- **Rint is independent on Vbias**
- **Values in GΩ range agree with specifications.**



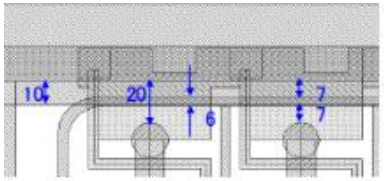




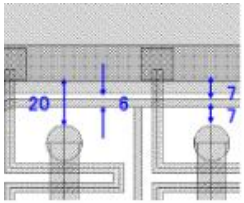
Punch-Through measurements



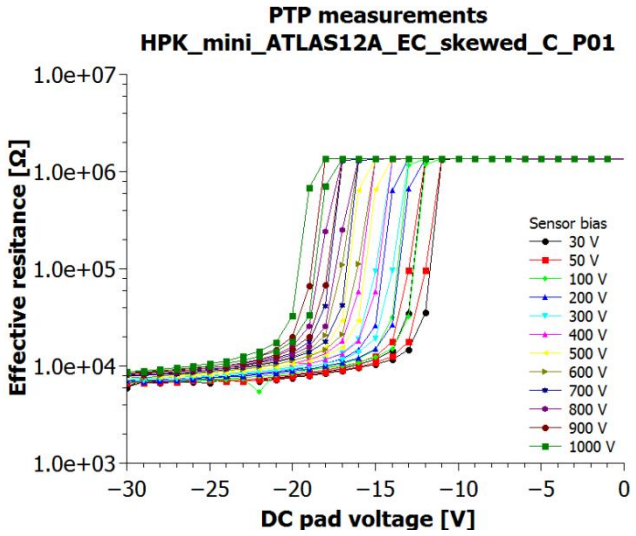
- Sensors biased at -300 V.
  - V_{PT} = 15.4 ± 1.2 V
  - R_{bias} = 1.4 ± 0.2 MΩ
- Clear difference between "E" and "C" label sensors. "Gate-effect" on PTP zone on "C".
- V_{PT} vs sensor bias dependance.
  - Bigger variation for "E"-standard PTP structures.

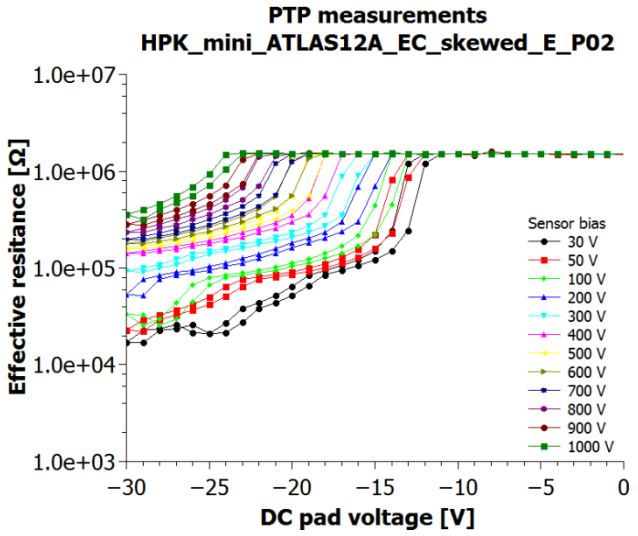


C



E





Freiburg/ Prague/ Valencia Results

- All measured parameters meet specifications
- Measurement results of all tree labs are similar

	Tech. Specification	Measurement
Leakage Current	< 2 µA/cm2 at 600 V	4.8 ± 1.5 nA/cm2
Full Depletion Voltage	< 300 V (for 4KΩcm)	354 ± 20 V
Coupling Capacitance at 1kHz	≥ 20 pF/cm	23.9 ± 0.7 pF/cm EC 25.0 ± 0.1pF/cm EC Skewed 27.4 ± 0.03pF/cm Barrel
Poly Silicon Bias Resistance	1.5±0.5MΩ	1.45 ± 0.04 MΩ
Punch-Trough Voltage		15.4 ± 1.2 V
Interstrip Capacitance to neighbour pair at 100kHz	< 0.8 pF/cm	0.79 ± 0.003 pF/cm Small Pitch 0.55 ± 0.007 pF/cm Large Pitch 0.74/0.76 ± 0.003 pF/cm Skewed (Top/Bottom Segm.) 0.78 pF/cm Barrel
Interstrip Resistance	> 10x Rbias ~ 15 MΩ	18-78 GΩ

Conclusions

Results up to now

- Electrical tests of 30 ATLAS12A EC mini sensors were performed in Freiburg, Prague and Valencia.
- Measurement results of all tree labs are similar.
- No breakdown was observed up to 600V/1000V sensor bias, leakage current more than 400x lower than Spec.
- Full Depletion Voltages of tested ATLAS12A sensors were found to be 340-380V which is higher than Spec. requirement < 300V assuming resistivity > 4kΩcm.
- Inter-strip capacitance and resistance as well as coupling capacitance and bias resistance satisfy Spec. for non-irradiated sensors.
- Much more better PTP performance for new PTP structure “C” with gate than with no gate “E”

Next steps

- Measurements of non-irradiated sensors will be continued for data verification.
- The same electrical tests of irradiated sensors by protons (5E14, 1E15, 2E15 Neq/cm2) and gamma (1, 3, 10 MRad) will be done to evaluate radiation damage (IV, CV, Cint, Rint, PTP) .
- Laser tests about charge distribution in ganging region using ALIBAVA readout before/after irradiation and CCE tests with ALIBAVA readout before/after irradiation are foreseen.

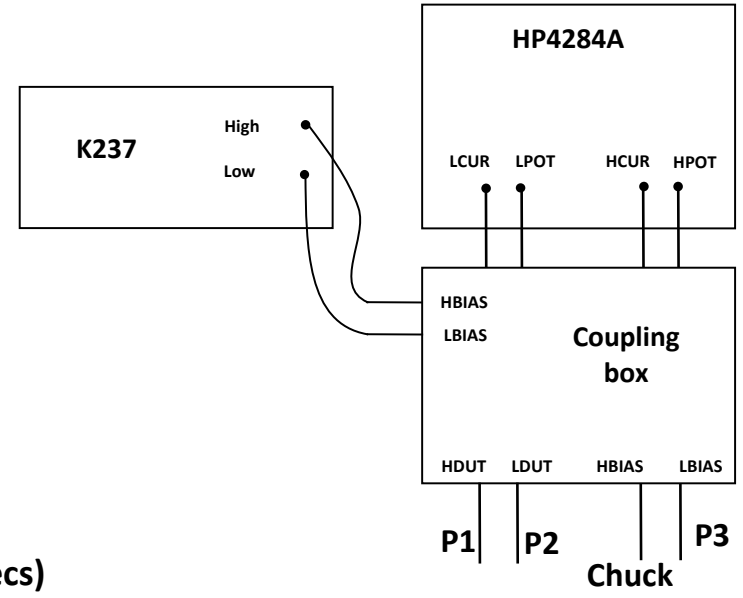
Backup

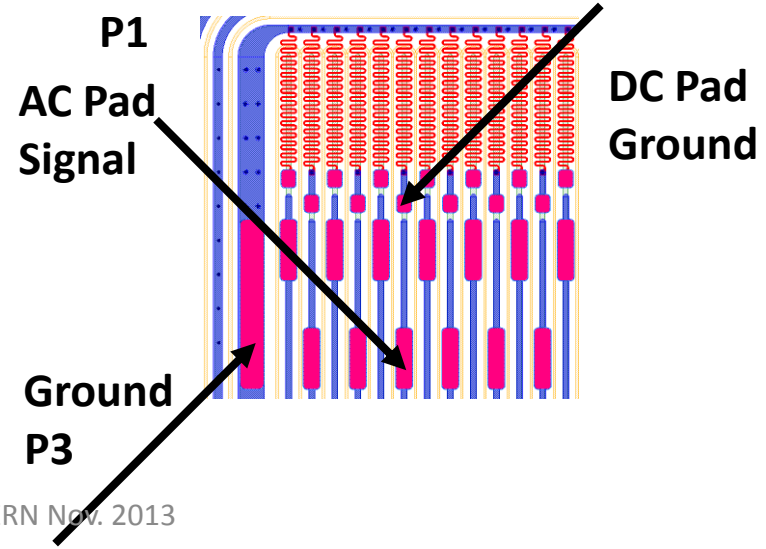
- Freiburg measurement setups
  - Coupling capacitance
  - Interstrip capacitance
  - Interstrip resistance
  - PTP measurement

- Prague measurement details

Coupling capacitance measurement

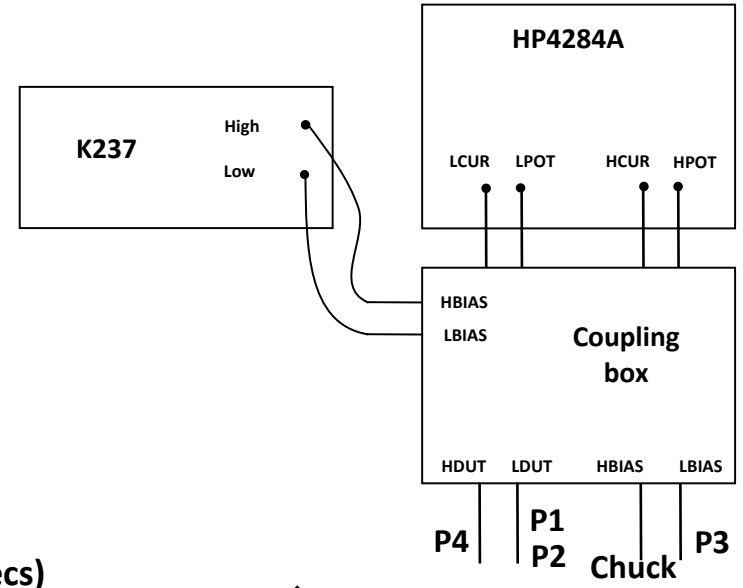
- HP4284A
  - Signal bias: 0 V
  - Frequency: 1 KHz
  - Model: Parallel CR
  - Signal level: 100 mV (no specs)
- K237
  - Voltage sweep: 0 V to -600 V
  - Voltage step: 1 V (no specs)
  - Current compliance: 200 uA (no specs)
- Expected value:
  - $C_{coupling}$> 20 pF/cm

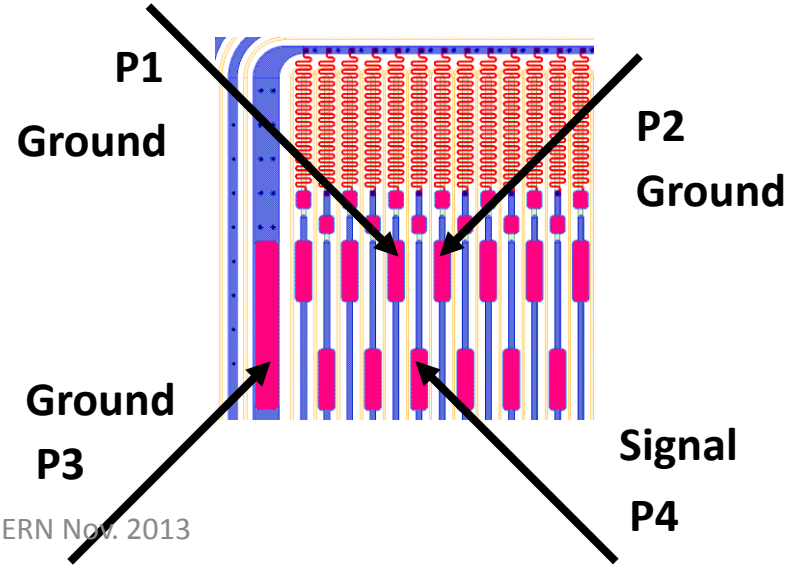




Interstrip capacitance measurement

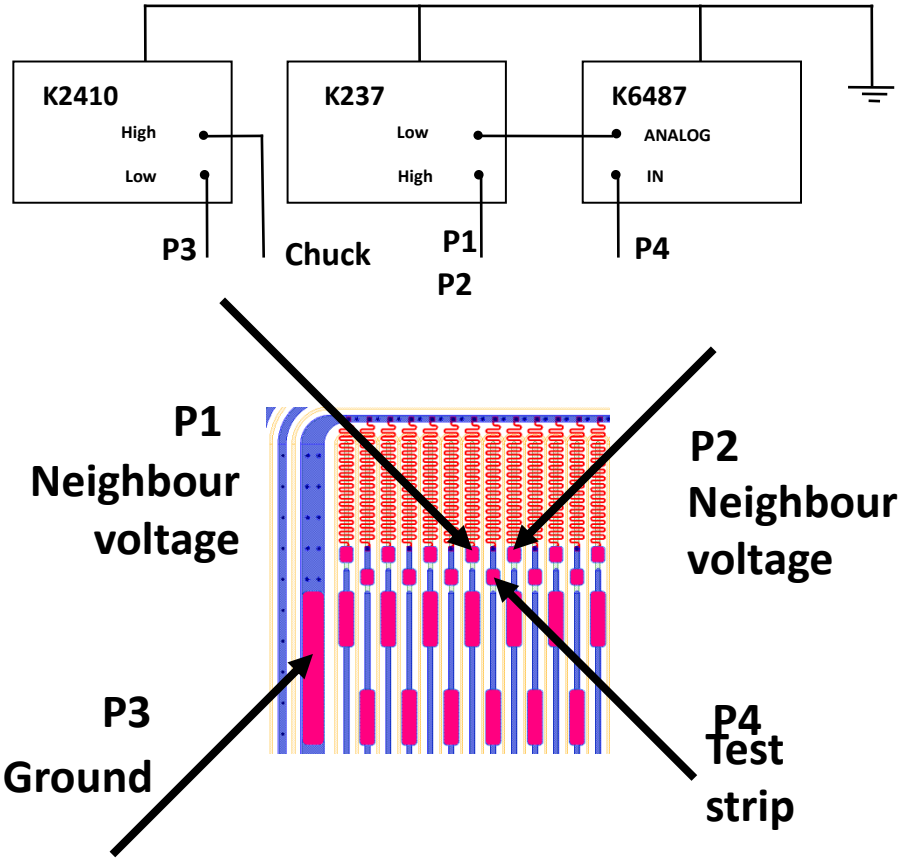
- HP4284A
  - Signal bias: 0 V
  - Frequency: 100 KHz
  - Model: Parallel CR
  - Signal level: 100 mV (no specs)
- K237
  - Voltage sweep: 0 V to -600 V
  - Voltage step: 1 V (no specs)
  - Current compliance: 200 uA (no specs)
- Expected value:
  - $C_{interstrip}$< 0.8 pF/cm @ 300 V





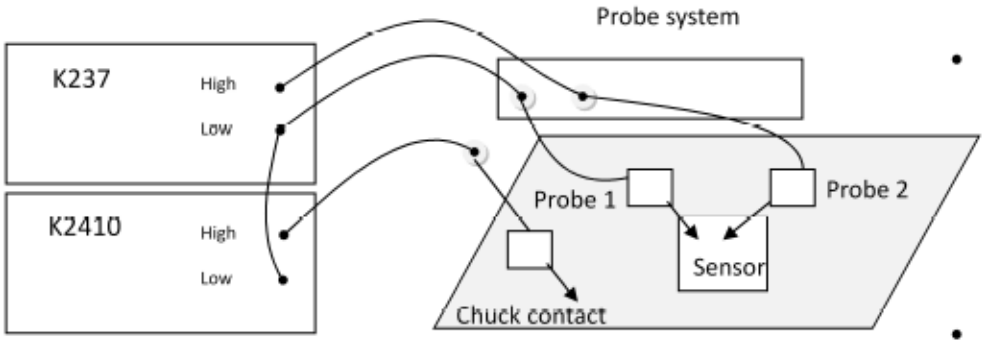
Interstrip resistance measurement

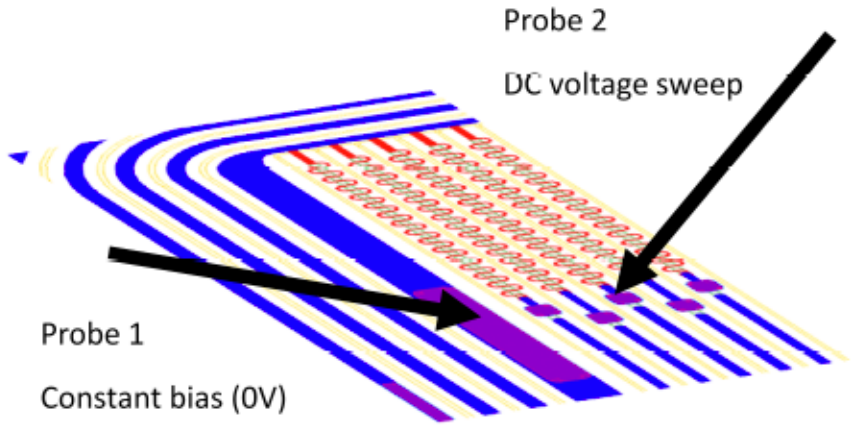
- K2410 (Sensor bias)
  - Voltage values: 1 V to 600 V
  - Current compliance: 200 uA
- K237 (Neighbour voltage)
  - Voltage sweep: -1 V to 1 V
  - Voltage step: 0.1 V
  - Current compliance: 10 uA
- K6487 (Test strip)
  - Measurement range: up to 2 nA
  - Read ratio: Slow
- Expected value:
  - $R_{interstrip}$> 15 MOhms @ 300 V



PTP measurement

Albert-Ludwigs-Universität Freiburg





- Room temperature ≈ 22 °C
- Constant and variable bias (K2410):
  - Vchuck = -300 V / 0 V to -1000 V
  - Vbias = 0 V

  Measure bias leakage current (200 uA compliance)
- DC voltage sweep (K237):
  - Vdc = 0 V to -35 V
  - 1 V steps

  Measure leakage current at DC pad (200 uA compliance)
- Vtest = Vdc-Vbias
  Reff= ΔVtest/ΔIdc
  |Idc| ≈| Ibias|

Prague measurement details

- **Temperature 21-22°C**
- **Humidity 30-35%**
- **20V step from 0V to 600V**

- **Equipment:**
  - **SMU: K237**
  - **precision LCR meter: HP4284A**
  - **electrometer/ voltage source: K6817A**
  - **multimeter HP34401A for measurement of resistivity of temperature chip PT100 which is connected with chuck.**
  - **Picoammeter/ Voltage source: K487**
  - **HV source: K248**
  - **probestation CarlSuss P200**

- **IV and CV:**
  - **10s delay between measurements = stabilization**
  - **LCR: at 1kHz with CR in SERIES**

- **Cinterstrip**
  - **6s delay between measurements**
  - **LCR: at 100kHz, CR in PARALLEL**

- **Ccoupl:**
  - **6s delay between measurements**
  - **LCR: at 1kHz, CR in PARALLEL**

- **Rinterstrip:**
  - **K248 (Sensor Bias: 50V, 100V, 200V, 300V, 400V,500V)**
  - **K237 (Neighbour voltage: -5V to +5V, Voltage step 1V)**
  - **K487 (Test Strip) measuremet range 2nA**