Simulation of new P-type strip detectors with trench to enhance the charge multiplication effect in the n-type electrodes

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Introduction

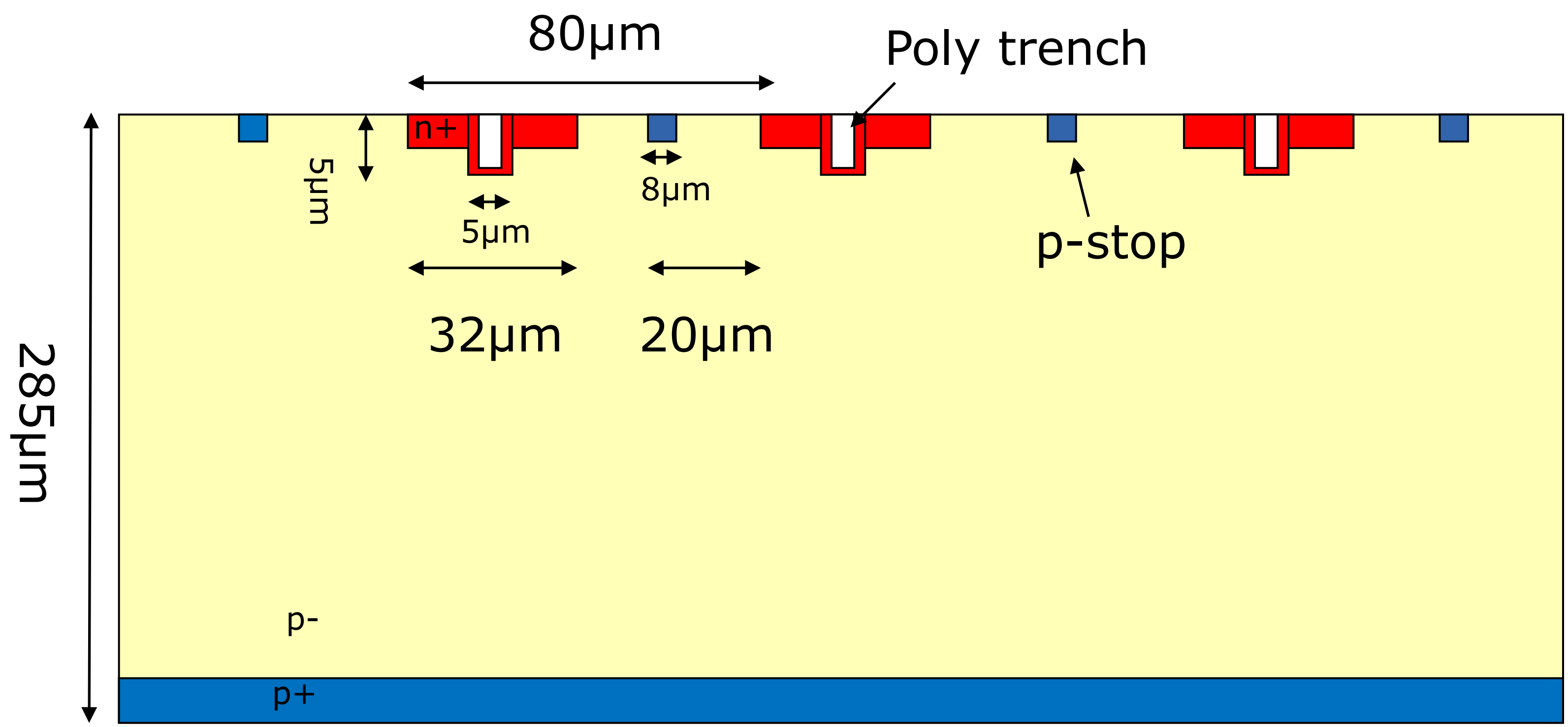
Project: fabricate a p-type strip detector with small gain → Similar signal before and after irradiation

- **Multiplication occurs at low bias voltage**
- **Gain should be limited between 2 and 10:**
  - **Avoid Crosstalk**
  - **Avoid exceeding the dynamic range of readout electronics**
- **Capacitance should not increase significantly**
  - **Higher capacitance → Higher noise**

Technological proposals

I. Trench filled with doped polysilicon along the centre of the strip pitch

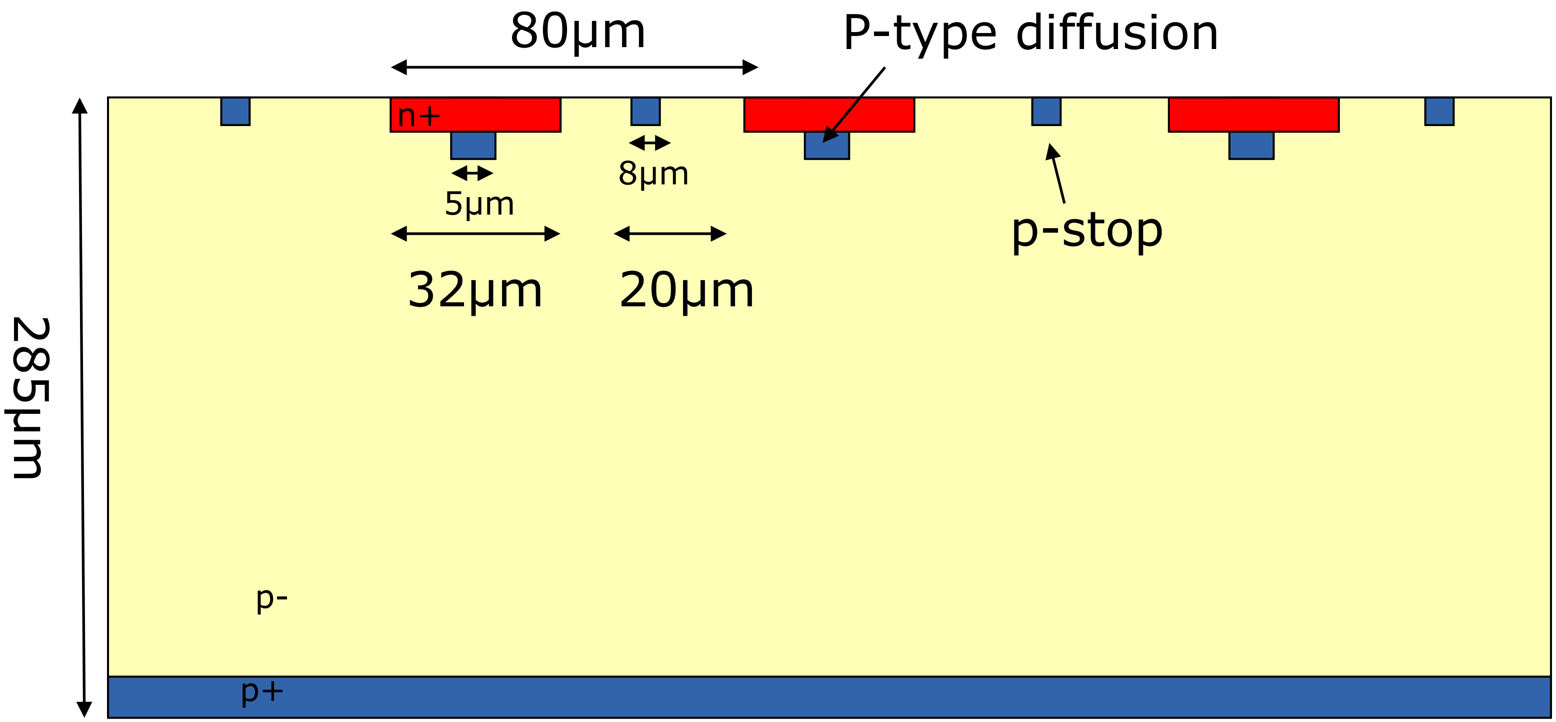
- **A N^+ contact is created into the silicon bulk that modifies the electric field in the collection region → multiplication**



Technological proposals

II. P-type diffusion along the centre of the strip pitch

- **Under reverse bias conditions, a high electric field region is created at the N⁺– P junction → multiplication**



Simulation Model

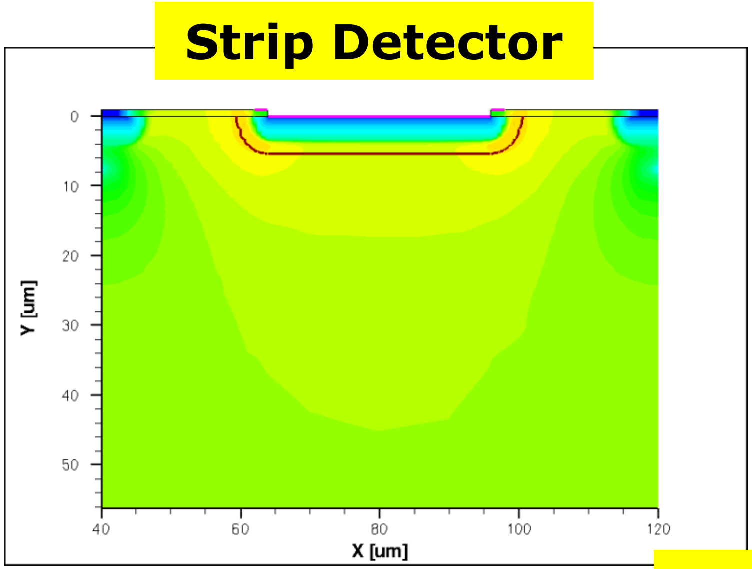
Sentaurus ISE-TCAD

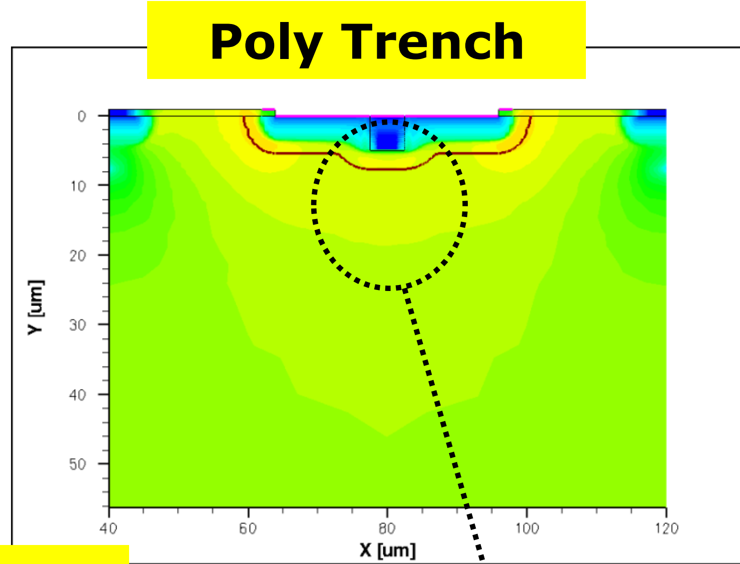
- **Impact Ionization Model: Universty of Bolonia**

- **Irradiation trap model:**

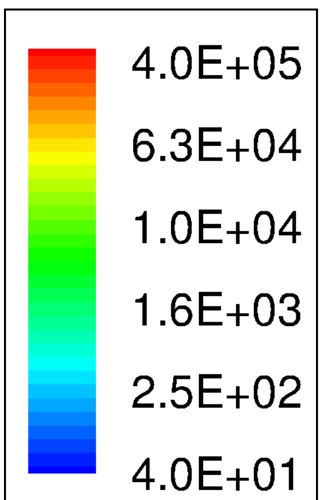
Acceptor;	**$E = E_c + 0.46$ eV;**	**$\eta=0.9$;**	**$\sigma_e = 5 \times 10^{-15}$;**	**$\sigma_h = 5 \times 10^{-14}$**
Acceptor;	**$E = E_c + 0.42$ eV;**	**$\eta=1.613$;**	**$\sigma_e = 2 \times 10^{-15}$;**	**$\sigma_h = 2 \times 10^{-14}$**
Acceptor;	**$E = E_c + 0.10$ eV;**	**$\eta=100$;**	**$\sigma_e = 2 \times 10^{-15}$;**	**$\sigma_h = 2.5 \times 10^{-15}$**
Donor;	**$E = E_v - 0.36$ eV;**	**$\eta=0.9$;**	**$\sigma_e = 2.5 \times 10^{-14}$;**	**$\sigma_h = 2.5 \times 10^{-15}$**

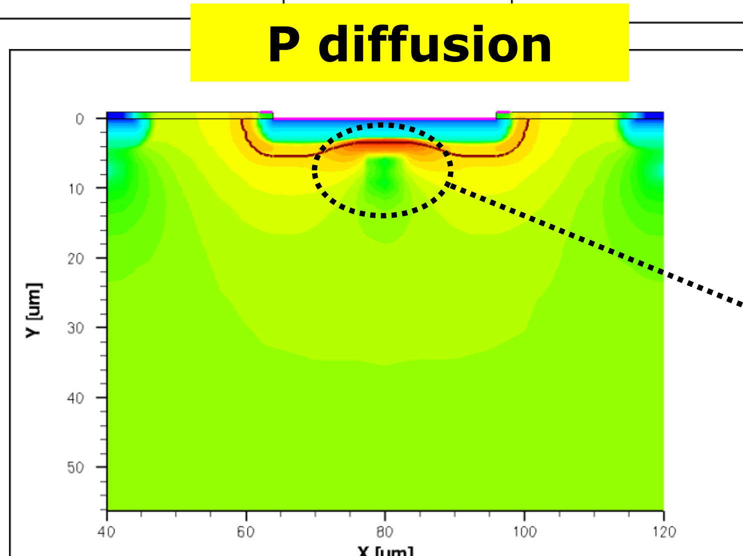
Simulation of the Electric Field





High Electric Field region driven deep in the bulk





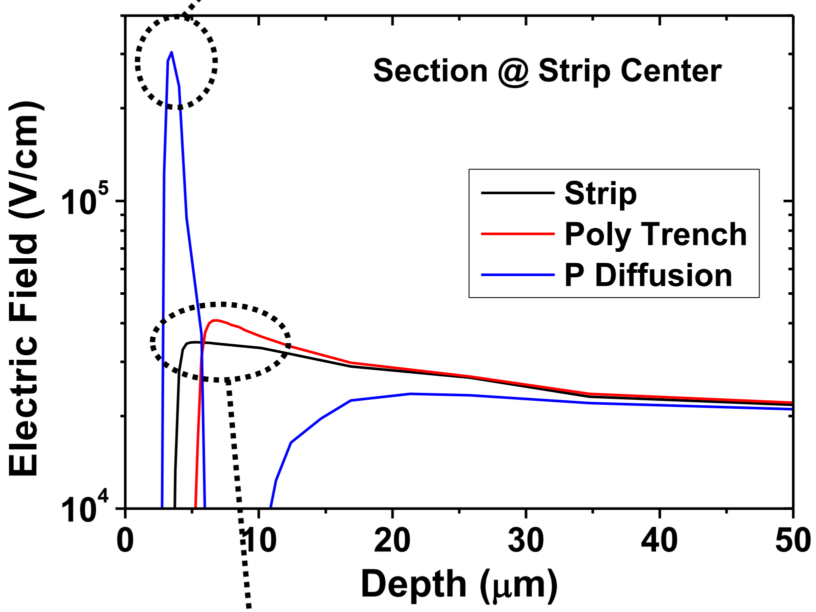
High Electric Field peak at the centre of the strip

Simulation of the Electric Field

High Electric Field peak at the junction

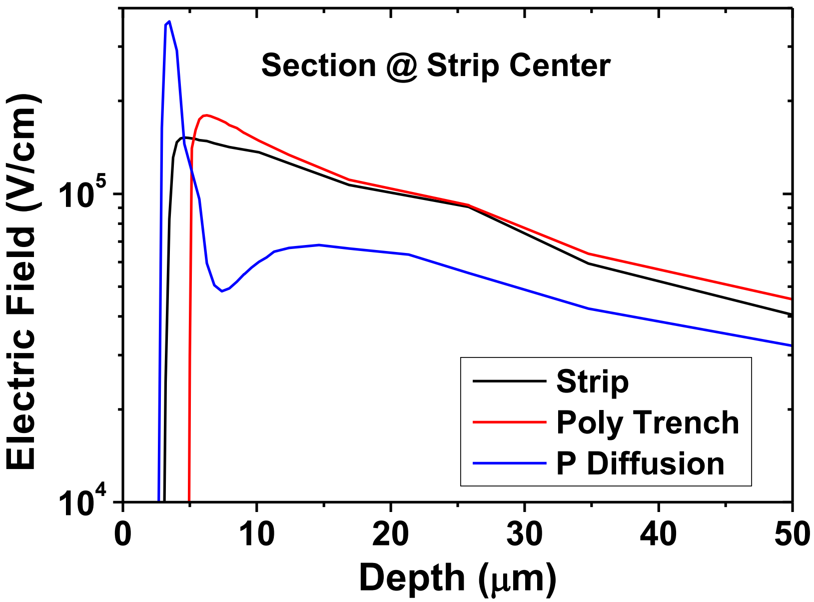
Curves at 500 V

No Irradiated

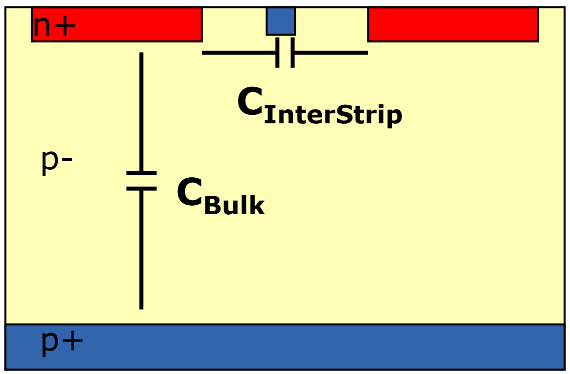


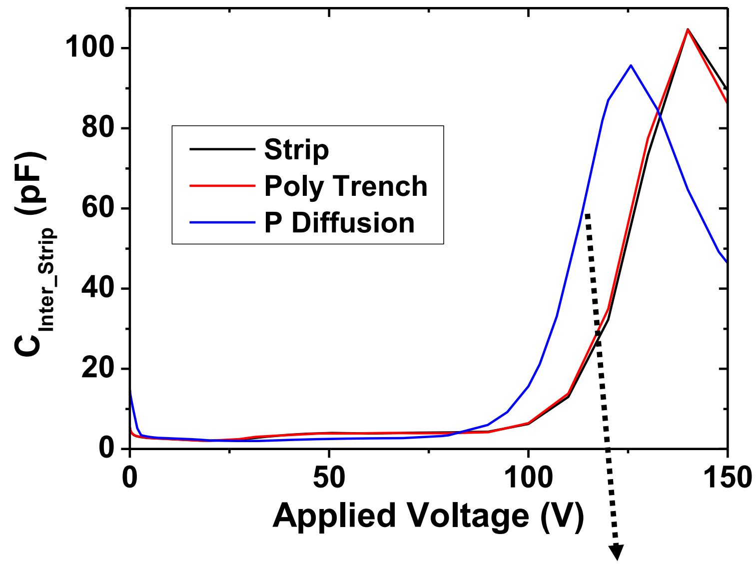
High Electric Field region driven deep in the bulk

Irradiated. Φ_{eq} = 1 x 10^{16}

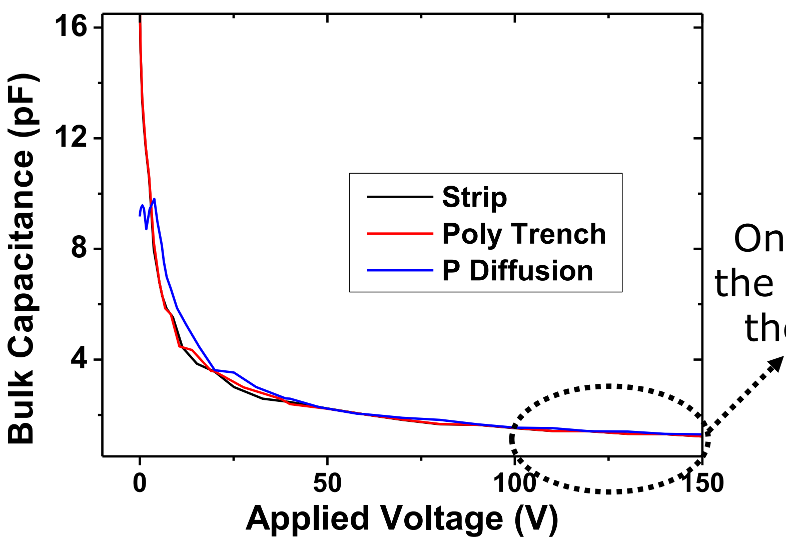


Simulation of the Capacitance





Increment related with the depletion of the P diffusion

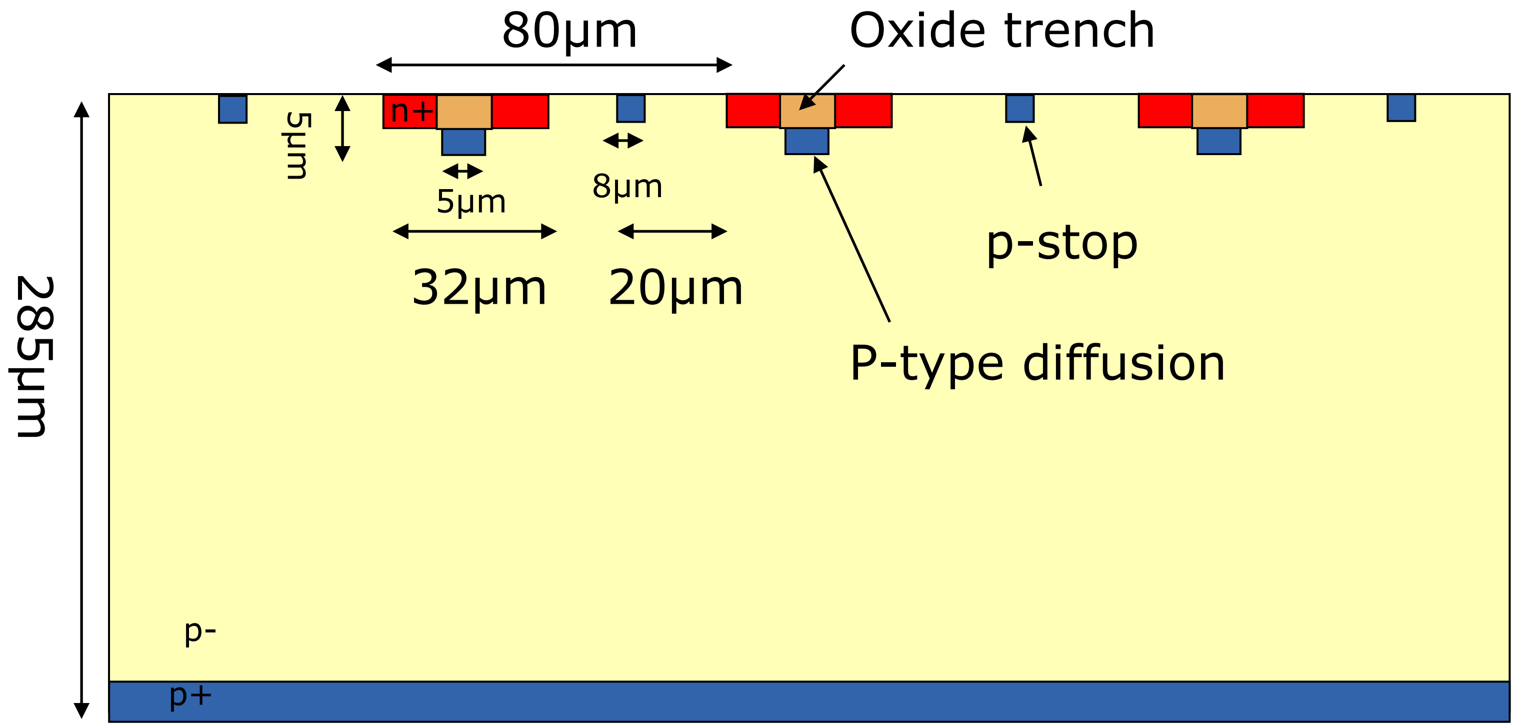


Once Fully Depleted, the bulk capacitance is the same for all the structures

✓ We need experimental results to extract any conclusion

Variation over the basic proposals

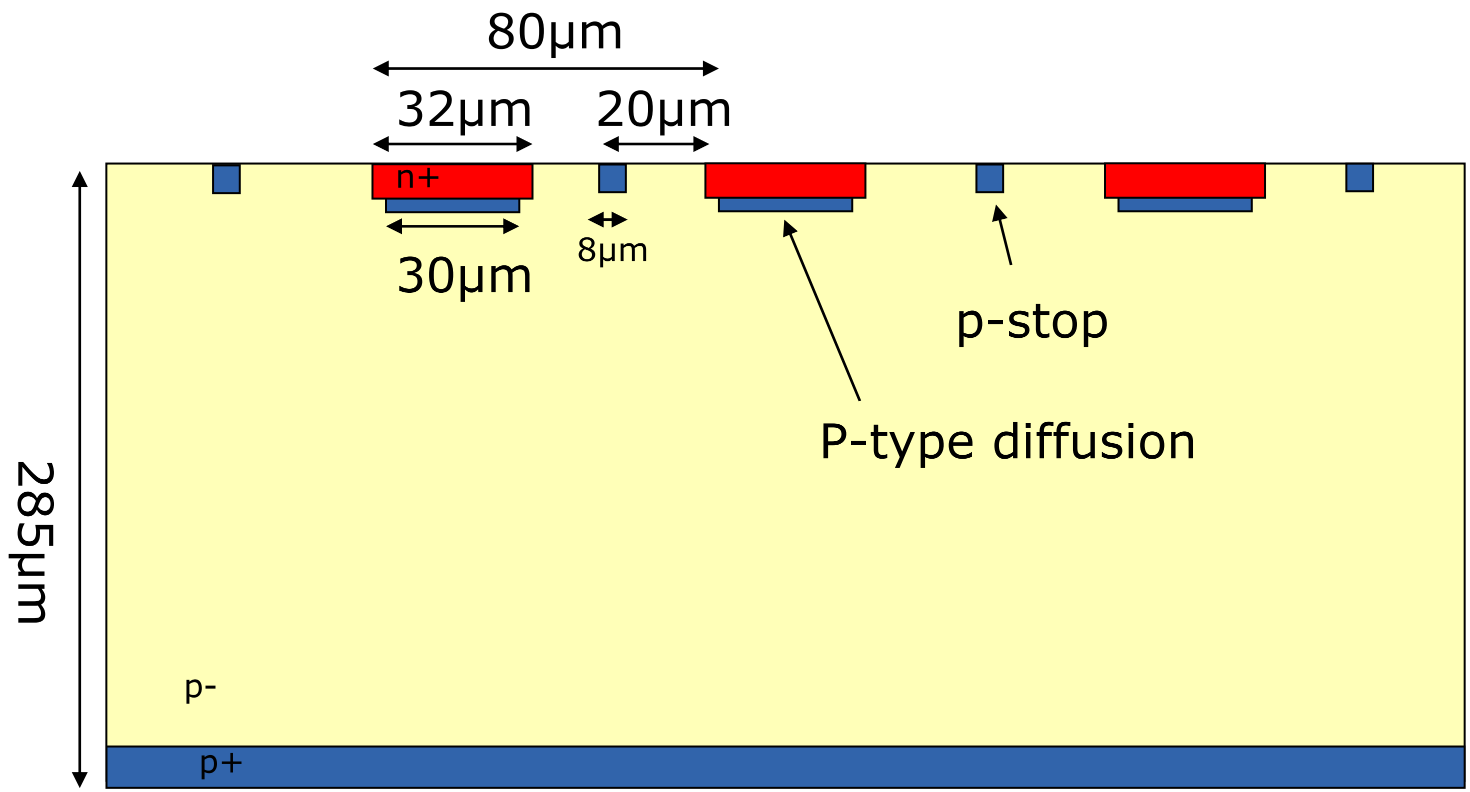
I. **P – type diffusion, implanted through a trench filled with oxide, along the centre of the strip pitch**
   - **N+/ P-type diffusion junction creates a high electric field region → multiplication**



Variation over the basic proposals

II. Large P-Type covering all the strip width

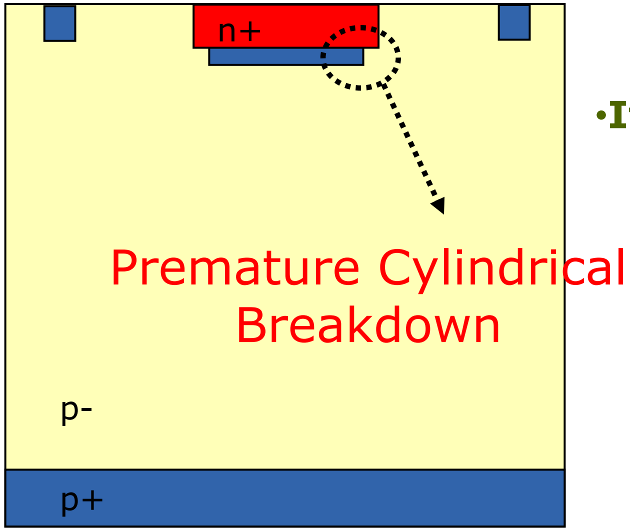
- **N⁺/ P-type diffusion junction creates a high electric field region → multiplication**



Variation over the basic proposals

DRAWBACK: If N^+ and P diffusions are performed with the same mask, a premature breakdown is expected due to the curvature of the junction

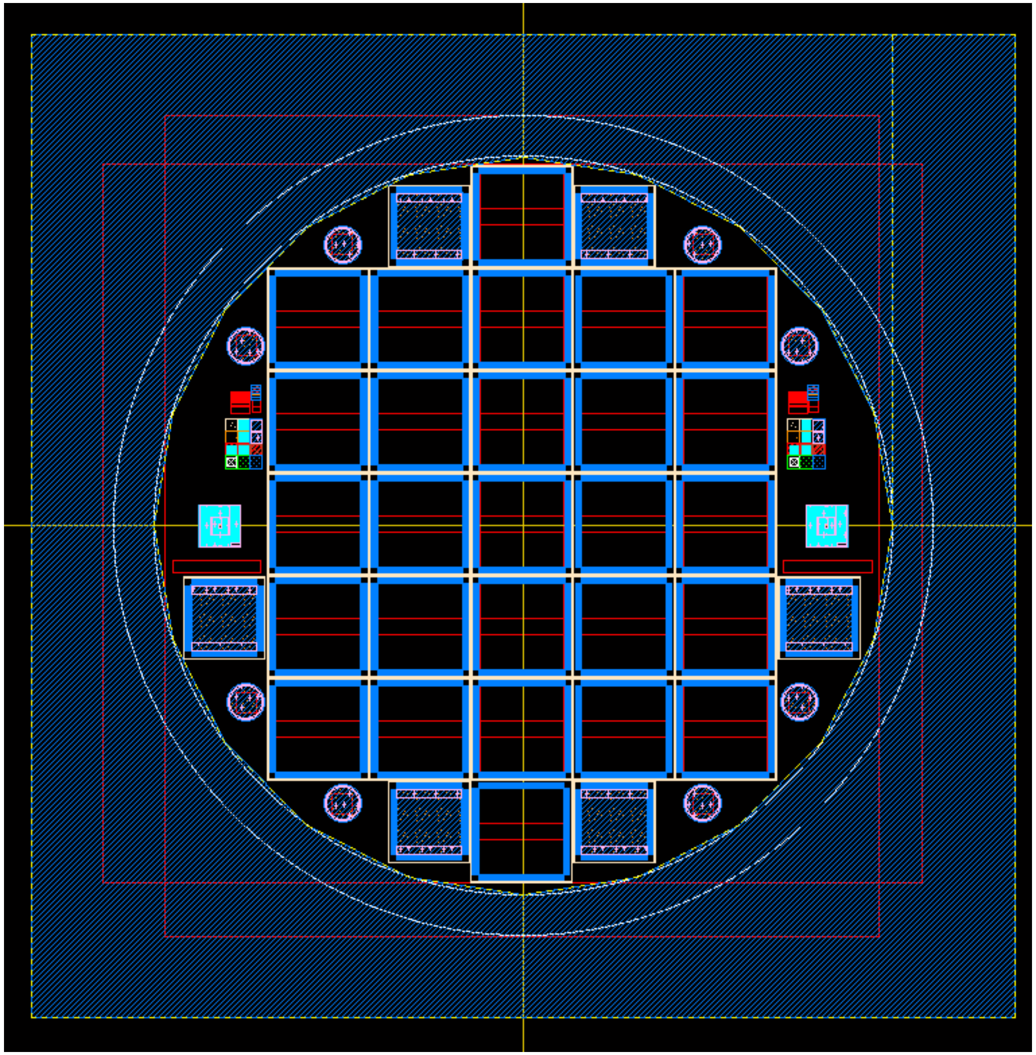
- **N^+ diffusion should overlap P diffusion**
  - **→ One extra level of Mask**
  - **→ Optimisation of the overlap size**
- **It should work after irradiation**



Status of the Work: Fabrication

The fabrication run includes:

- **Conventional Strip Detectors**
- **Poly Trench structures with different trench depths:**
  - **5 µm**
  - **10 µm**
  - **50 µm**
- **Structures with small P layer along the center of the strip**
- **Devices with large P layer along the center of the strip**
- **Oxide filled trench structures with a P layer implanted through the trench:**
  - **5 µm**
  - **10 µm**
  - **50 µm**

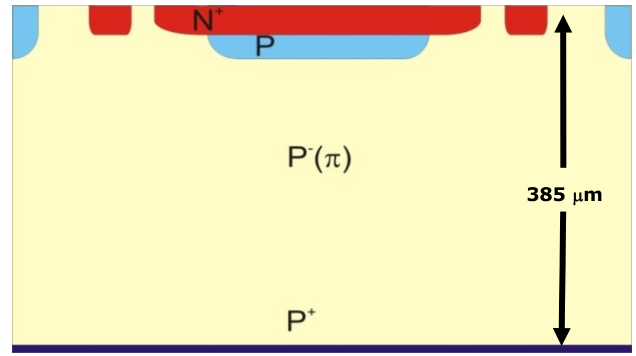


Fabrication: step 50 out of 80.
Doping trenches.

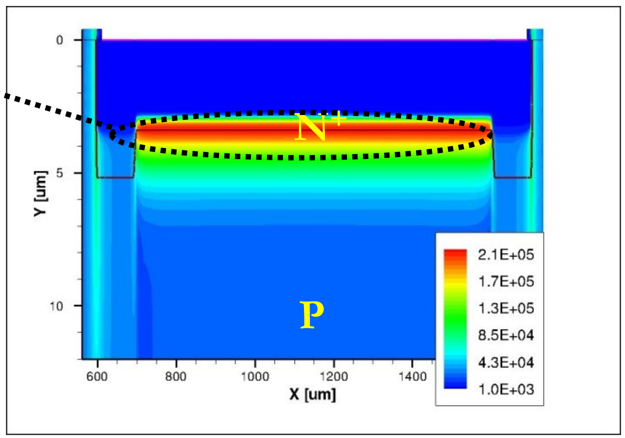
Status of the Work: PAD Diodes

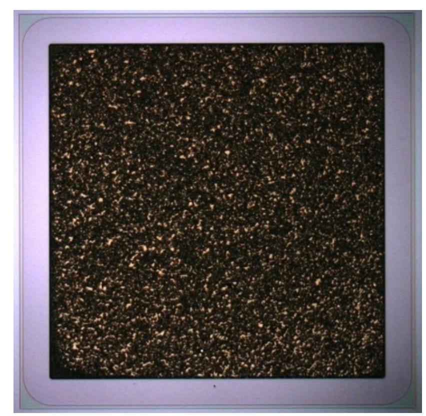
We have fabricated PAD diodes with a P layer diffused under the N^+ diffusion

- **N^+/ P-type diffusion junction creates a high electric field region →** **multiplication**



High Electric Field region leading to multiplication





5000 μm

5000 μm

✓ First Measurements: Gain ~2

Conclusions and Applications

1. **We have shown several new designs to enhance the multiplication process.**
2. **If detector will work many tests must be done: uniformity, stability, reproducibility etc.....**
3. **A PAD detector with small gain has been fabricated following some of the procedures described in this work.**
4. **A run containing the discussed designs is being fabricated for subsequent characterisation.**
5. **Test uniformity with test beam or laser with Alibava**

Applications:

- Radiation Hard Detectors
- Tracking Detectors
- Charge multiplication permits the fabrication of thinner detectors