Single Event Transients RHA Policy - Agencies

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Radiation Hardness Assurance

- Define radiation environment
  - Heavy ions (GCR, solar ions)
  - Protons (trapped, solar)
- Bound the part response
  - SET testing
- Define system /subsystem response to the radiation environment
  - SET criticality analysis
  - SET rate prediction

Available Documents

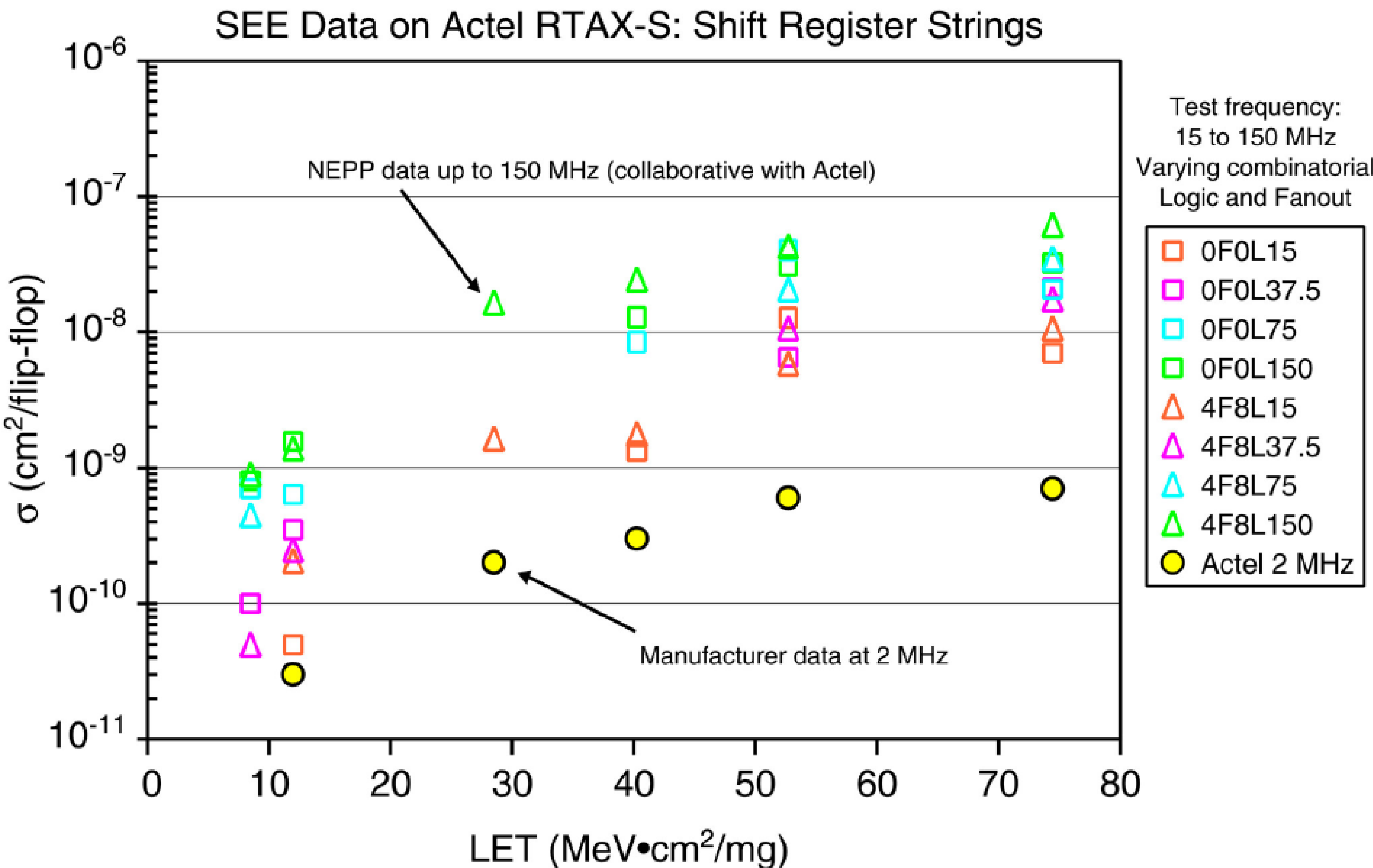
- Draft ECSS-Q-ST-60-15C
  - Space Product Assurance
    - Radiation Hardness Assurance

- ESCC25100 issue 1, October 2002
  - Single Event Effect Test Method and Guidelines

Bound the Part Response

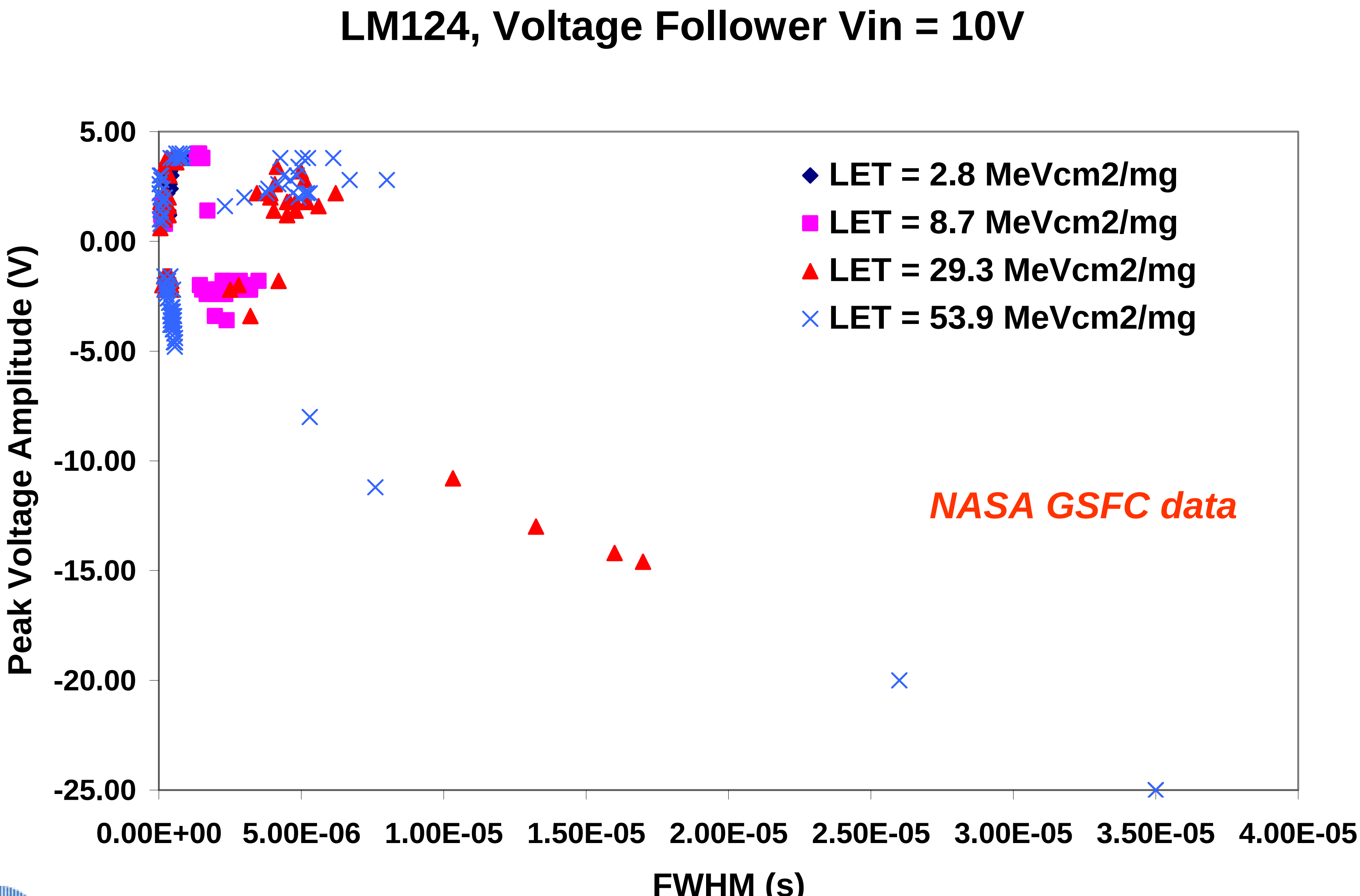
- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement a: No SEE shall cause damage to a system or a subsystem or induce performance anomalies or outages
    - Requirement b: **Each active electronic part shall be assessed for sensitivity to SEE effects**.
    - Requirement c: **If component test data does not exist, heavy ion ground testing shall be required**.
- ESCC25100 issue 1, October 2002
  - Section 4.2.1 Single Event Upset
    - "Analogue and mixed analogue/digital technologies may generate false outputs or transients as the result of SEE. The test system shall be capable of monitoring and logging these effects."

Bound the Part Response, Digital IC



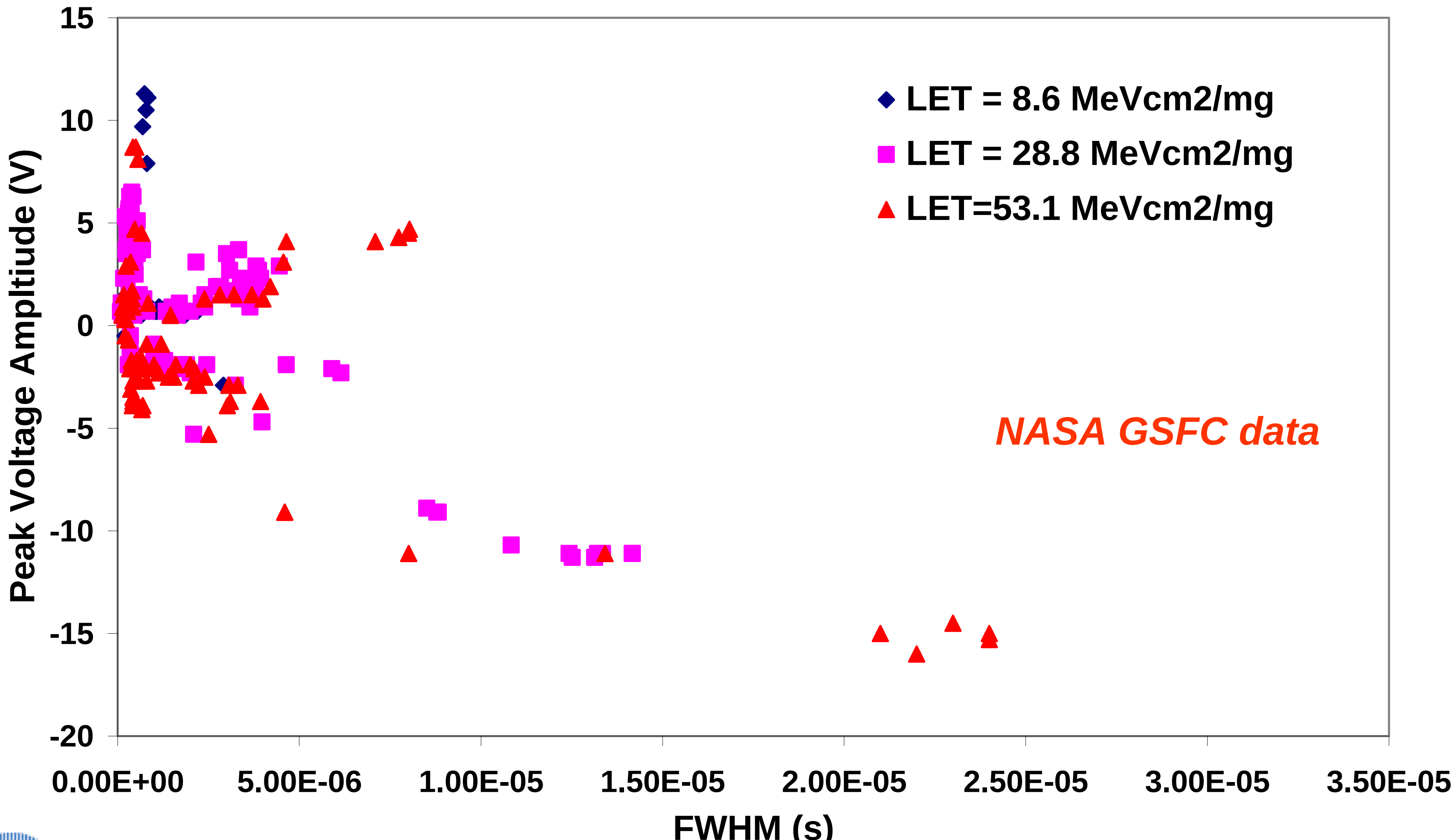
NASA GSFC data

Bound the Part Response, Analog IC



Bound the part response, Analog IC

LM124, Voltage Follower Vin=1V



Bound the part response

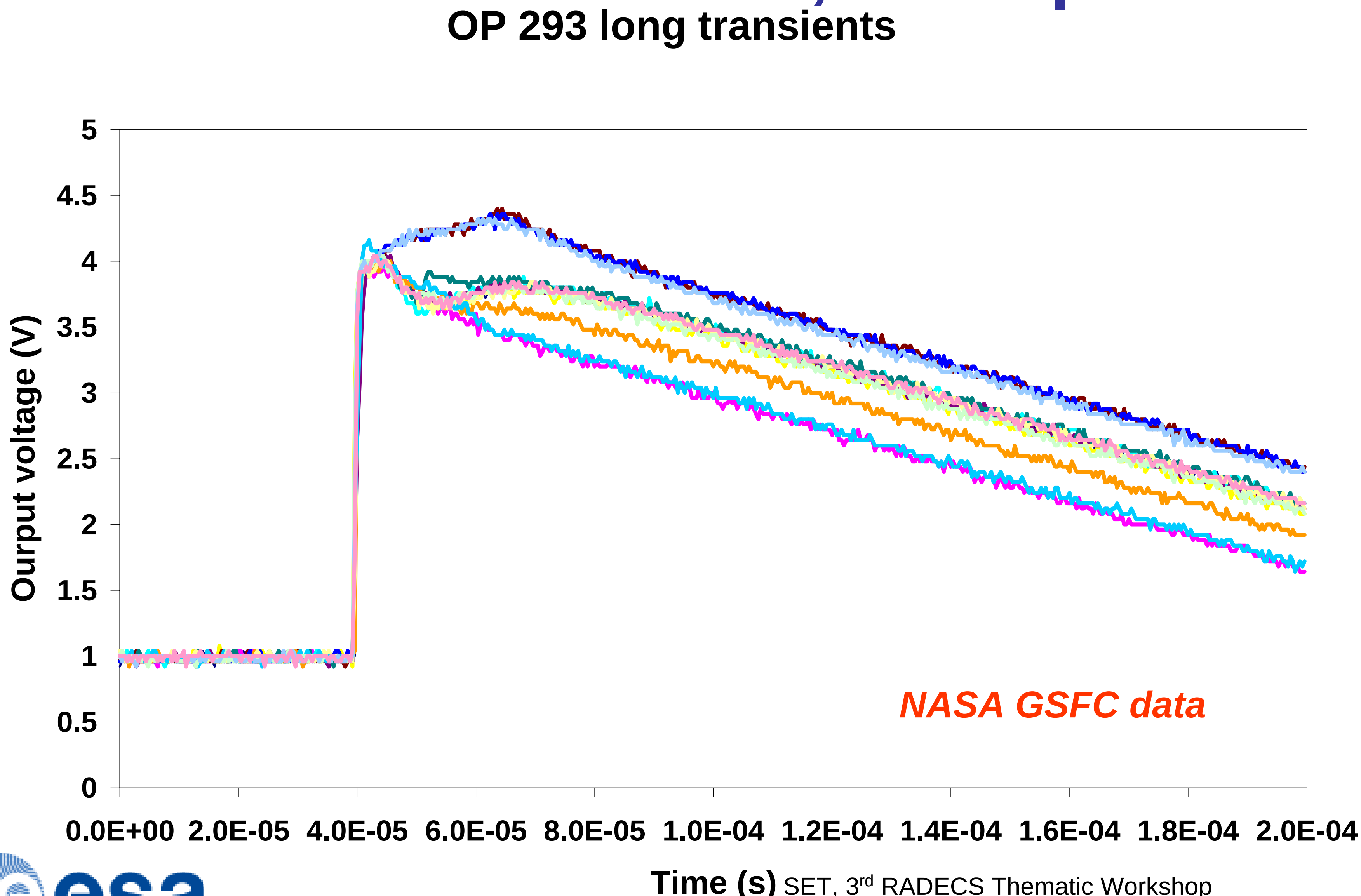
- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement e: All SEE testing shall be performed according to ESCC25100. Testing conditions shall be representative of application conditions. This shall include, but is not limited to: **bias conditions**, **clock frequency**…….

Bound the Part Response
Worst Case Models for analog ICs

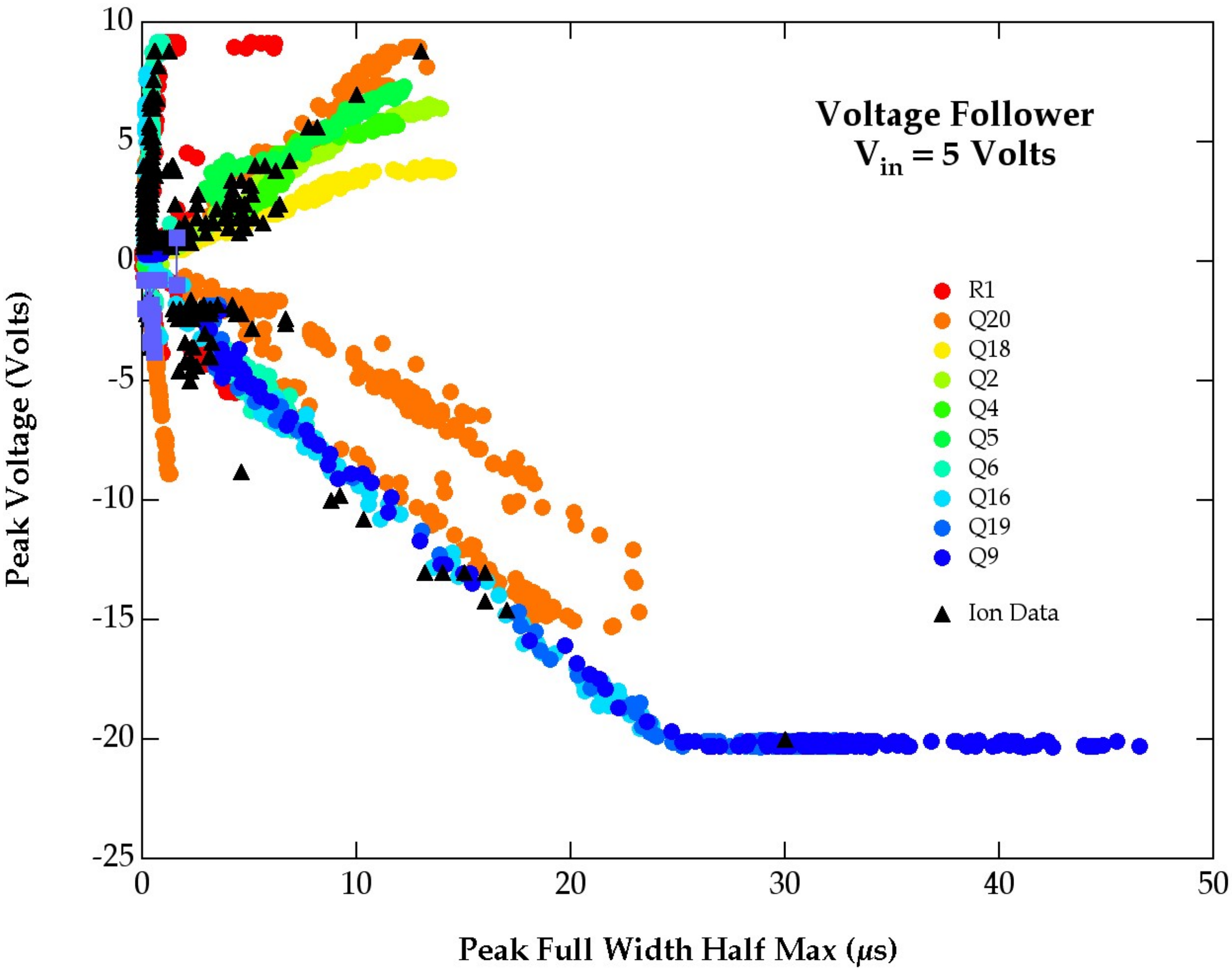
Operational amplifiers	ΔV_{max} = + / - Vcc & Δt_{max} = 40 µs
Voltage Comparators	ΔV_{max} = +/- Vcc & Δt_{max} = 10 µs
Voltage Regulators	ΔV_{max} = +/- Vcc & Δt_{max} = 10 µs
Voltage References	ΔV_{max} = +/- Vcc & Δt_{max} = 10 µs

From ALPHASAT RHA requirements

Bound the Part Response Worst case SETs, Example



Bound the Part Response
Obtain Worst case SET with laser



LM124,

heavy ion

(53 MeVcm^2/mg)

and laser data

After Buchner, SEE symposium 2004

Bound the Part Response

- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement c: If component test data does not exist, heavy ion ground testing shall be required.
      - Note: It is common practice to use a worst case SET model for the SET criticality analysis of analog ICs. This approach is not recommended. However, an approach using worst case SETs obtained from laser testing can be accepted.

Bound the part response
Proton induced SET

- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement i: Parts analysis and possibly proton testing shall take place based on LET threshold (LETth) of the candidate devices. Above a LETth of 75 $MeVcm^2/mg$, the parts can be considered as immune to SEE in space and no further analysis is required. Below this level SEE analysis shall be performed. And, below a LETth of 15 $MeVcm^2/mg$ proton induced sensitivity analysis shall be analyzed as well, and **proton test data shall be required**.

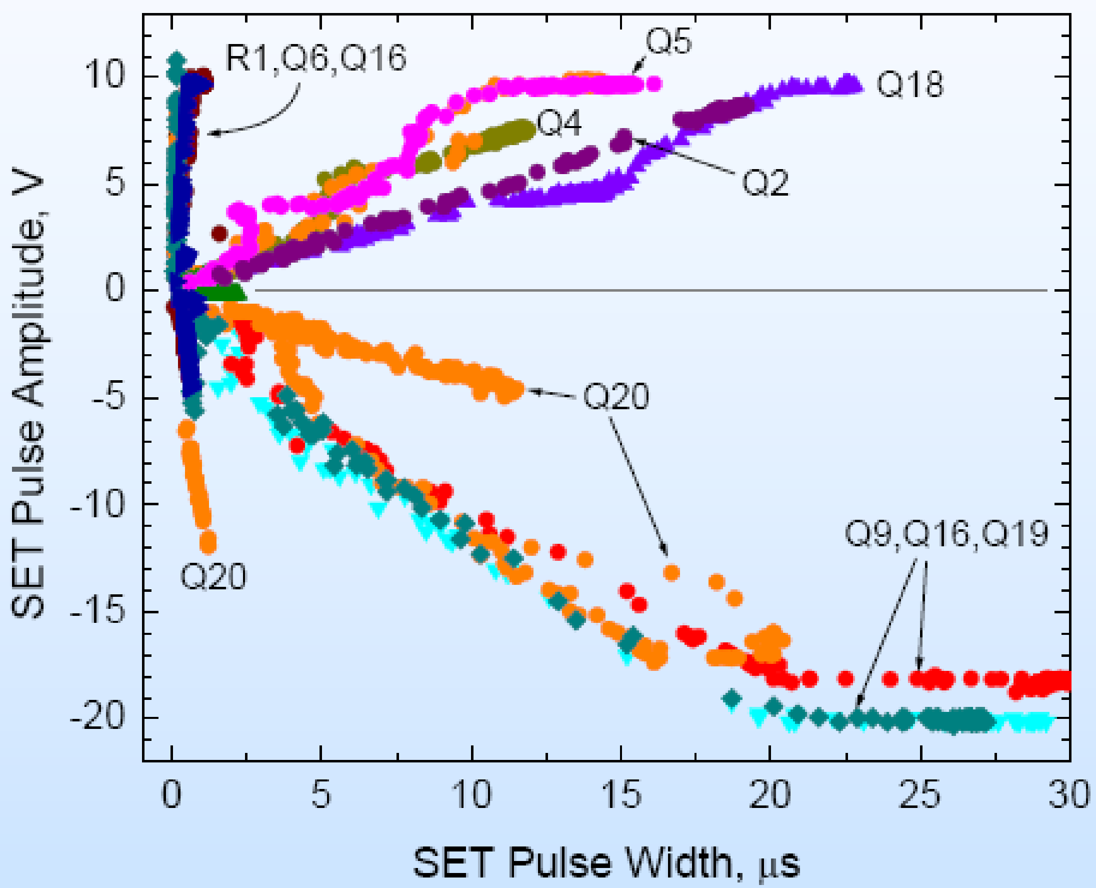
SET criticality analysis

- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement k: for non destructive events like SEU, SET, and MBU, the criticality of a component in its specific application shall be defined including all possible impacts at higher, subsystem and system, levels

SET event rate calculation

- Draft ECSS-Q-ST-60-15C
  - Section 5.3 SEE hardness assurance
    - Requirement l: When a SEE on a given component for a given application is considered critical or potentially critical, the mission event rate shall be calculated according to the methods described in ECSS-E-ST-10-12C. This rate shall be calculated for the mission background environment and a solar event environment as well as defined in mission radiation environment specification. A RDM of 10 shall be applied on event rates.

SET event rate calculation in analog ICs
Number of sensitive nodes/volumes



LM124, laser data

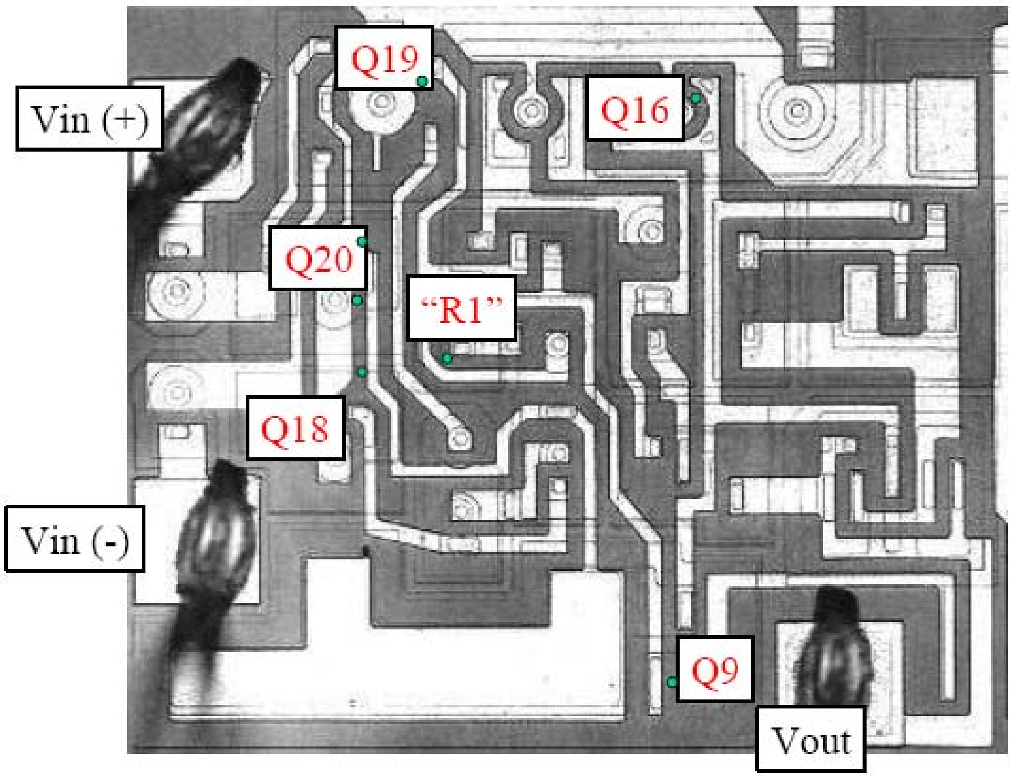
After Buchner, SEE symposium 2004

SET event rate calculationin analog ICs number of sensitive nodes/volumes

- Example: LM139
  - Effect of the number of sensitive nodes

Number of sensitive nodes	Sensitive node area (μm2)	# GCR induced SET CREME96, solmin (#/comparator-day)	# SPE induced SET CREME96, worst day (#/comparator-day)
1	60000	4.99E-03	1.63E+00
10	6000	4.83E-03	7.84E-01
100	600	4.34E-03	2.17E-01

SET event rate calculation in analog ICs
Thickness of sensitive volume



LM124

After McMorrow, SERESSA 2006

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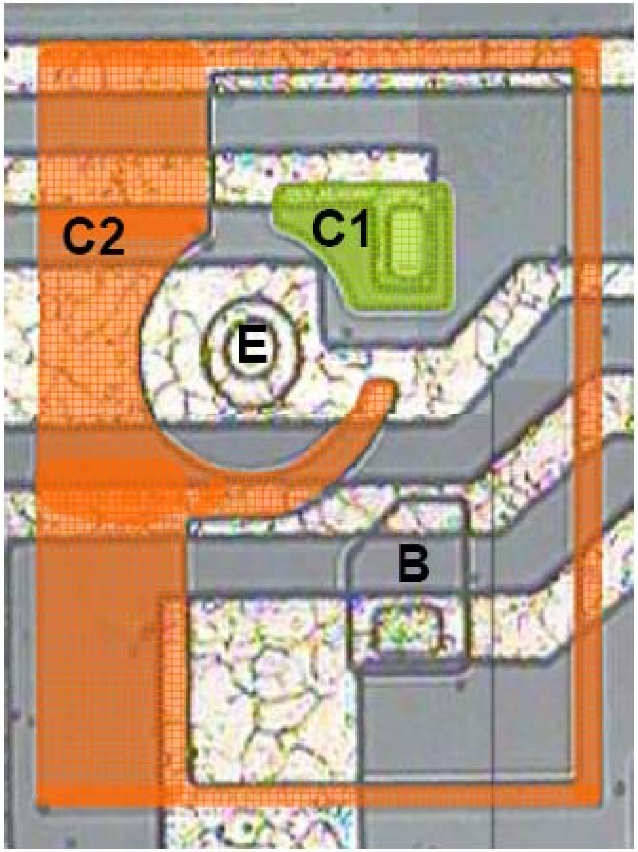

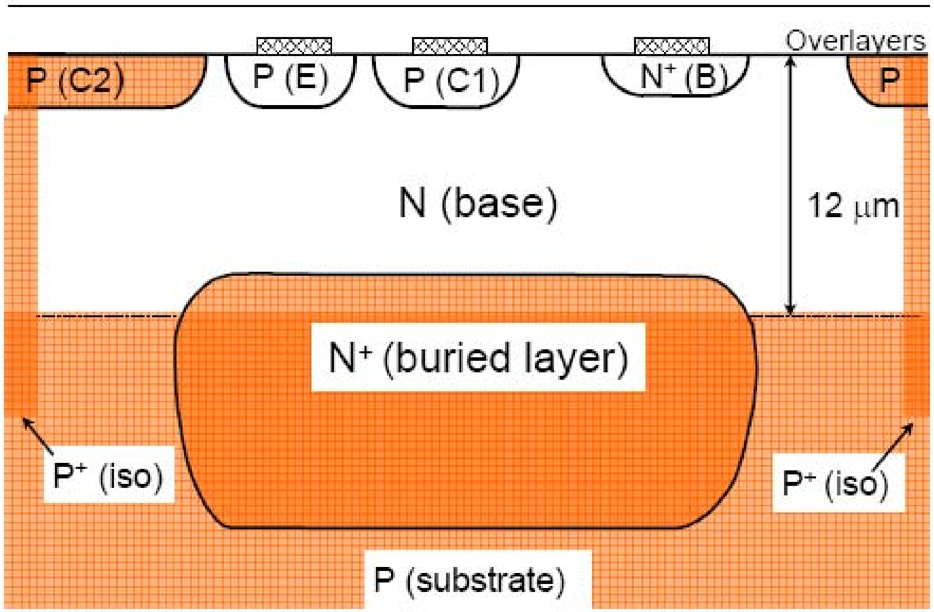

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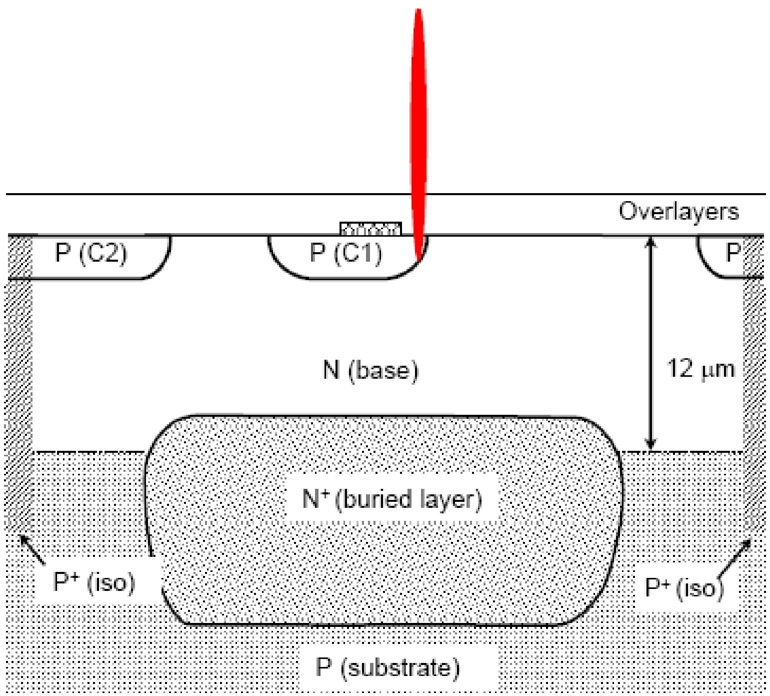
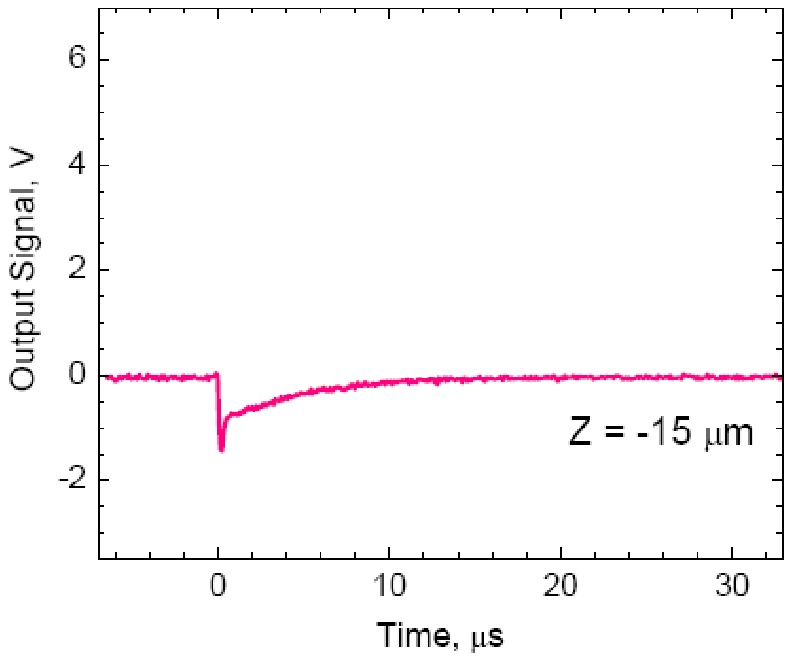


Inverting Configuration, gain of 20



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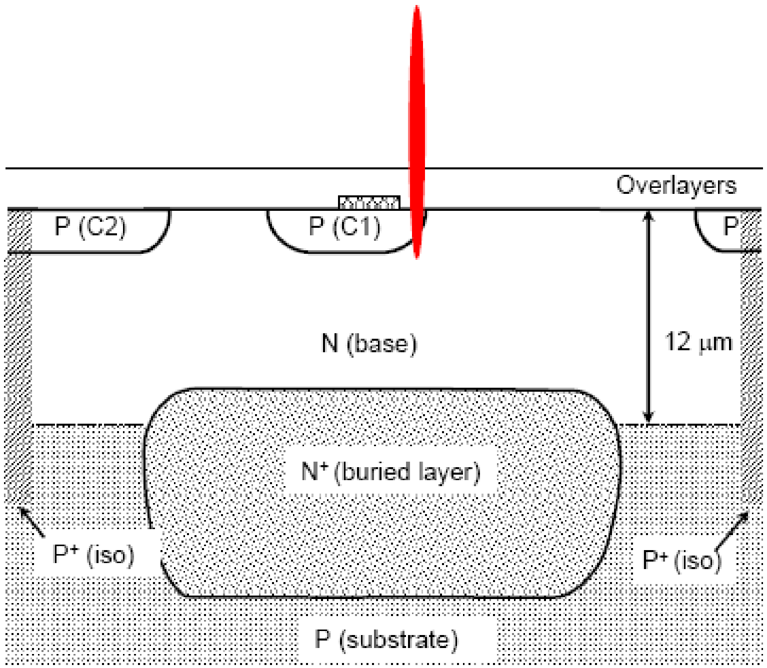

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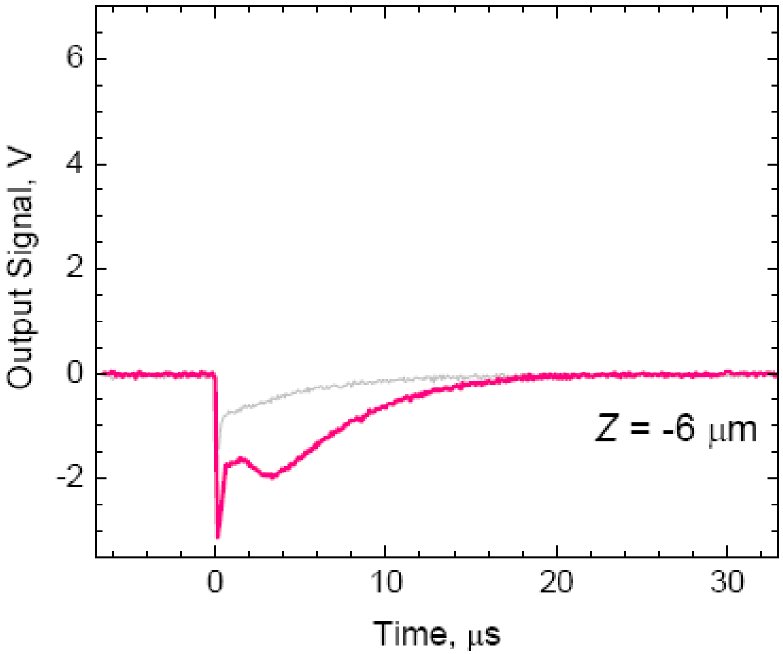

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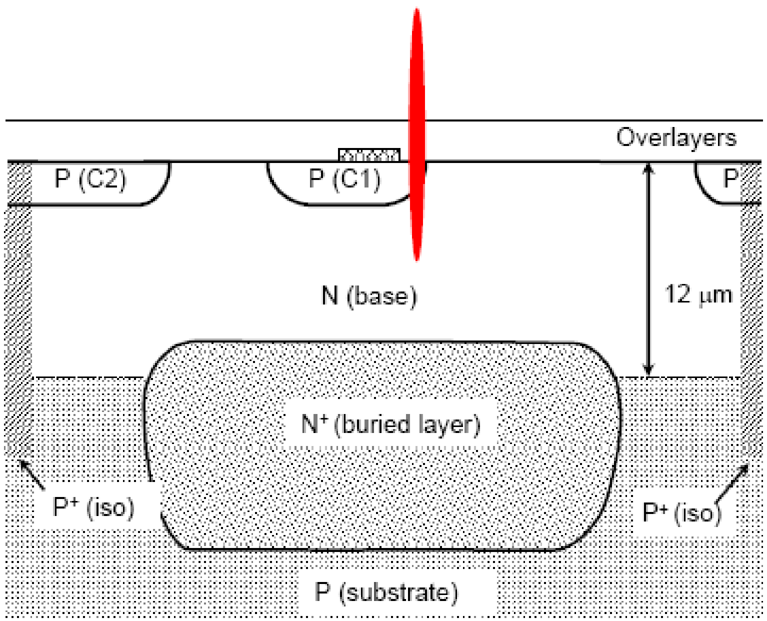

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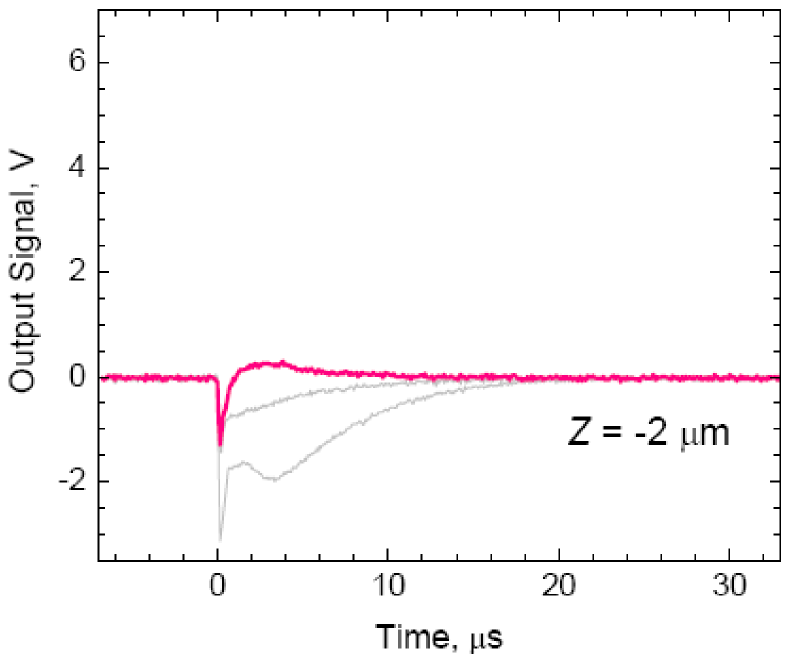

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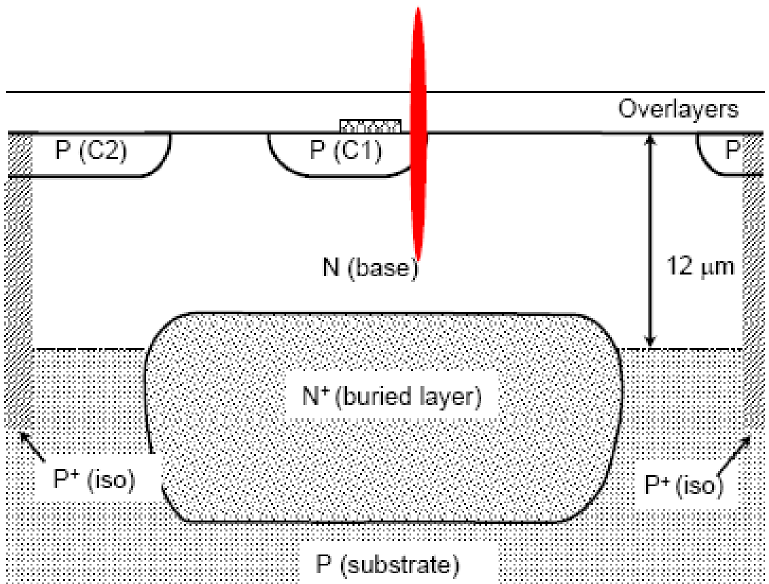

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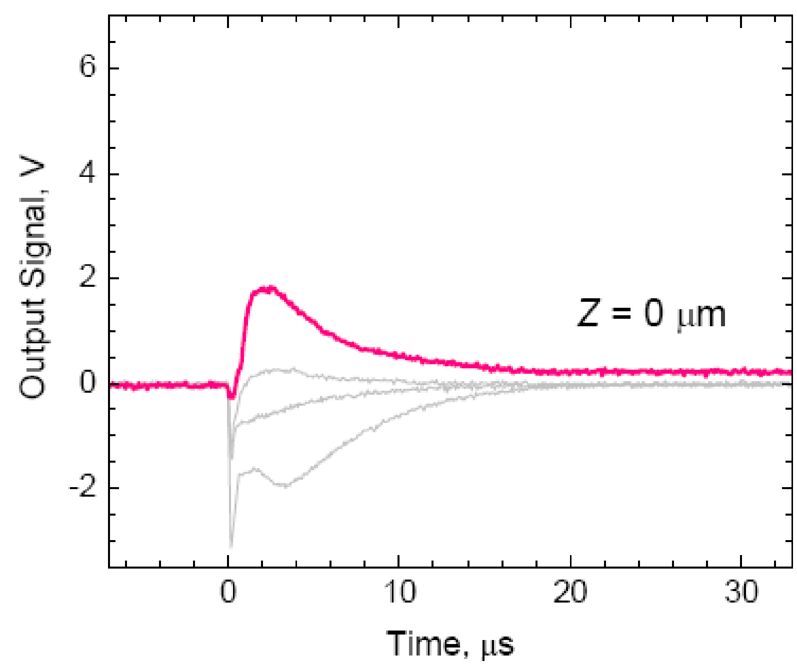

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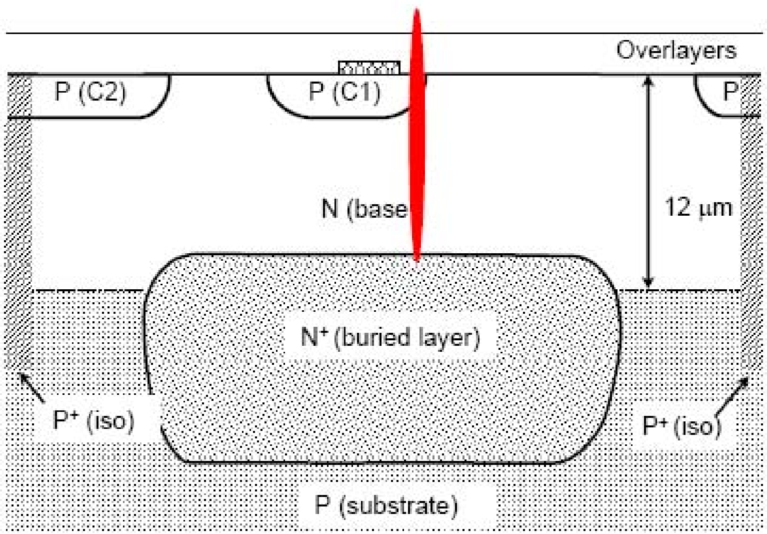

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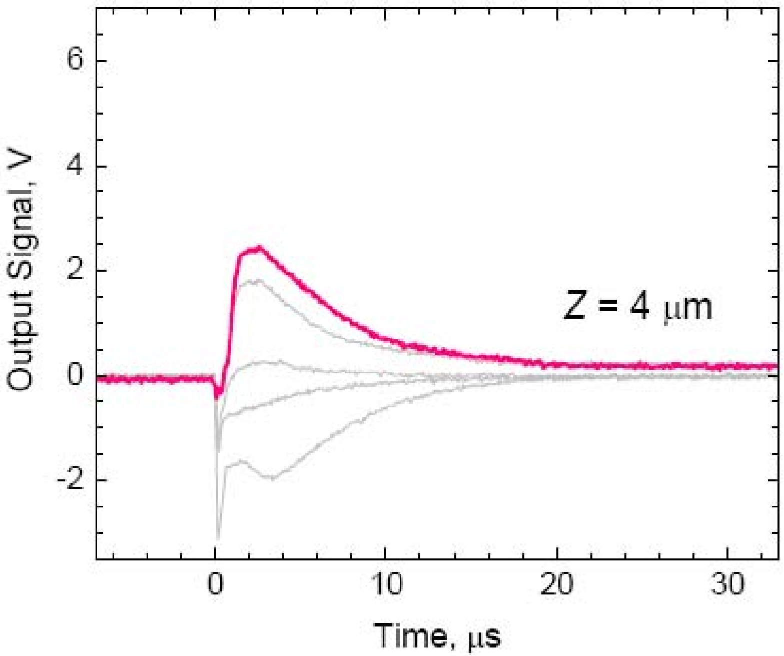

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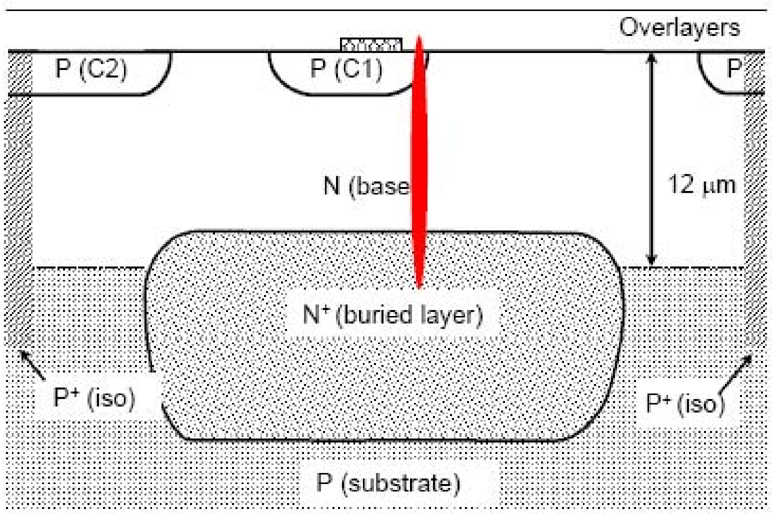

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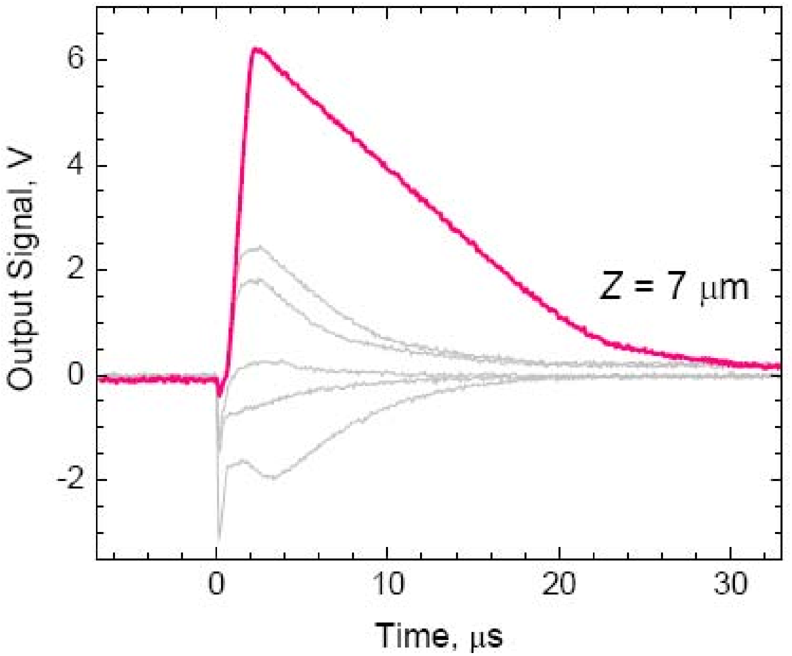

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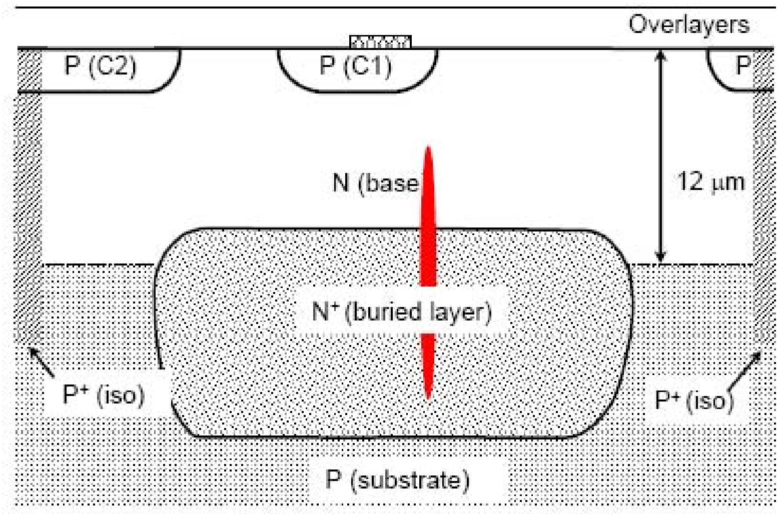

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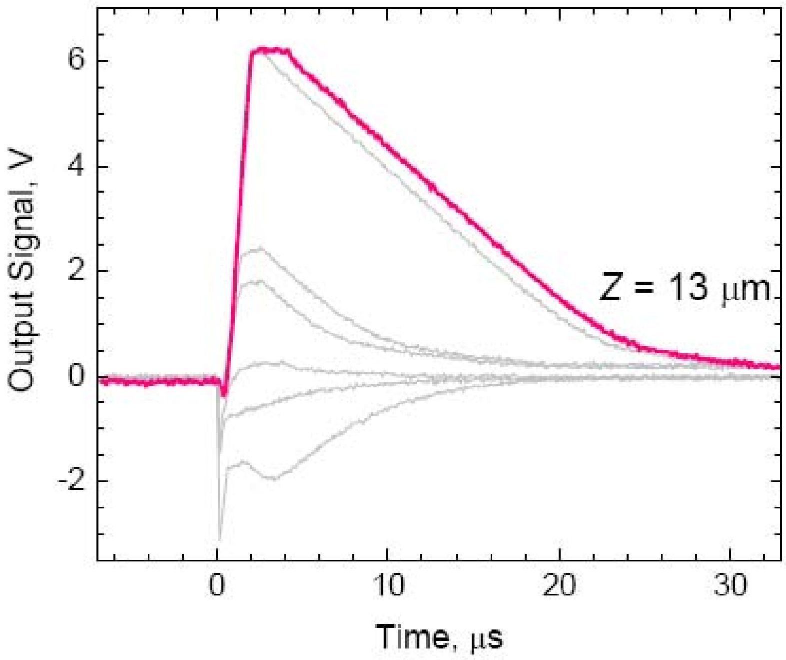

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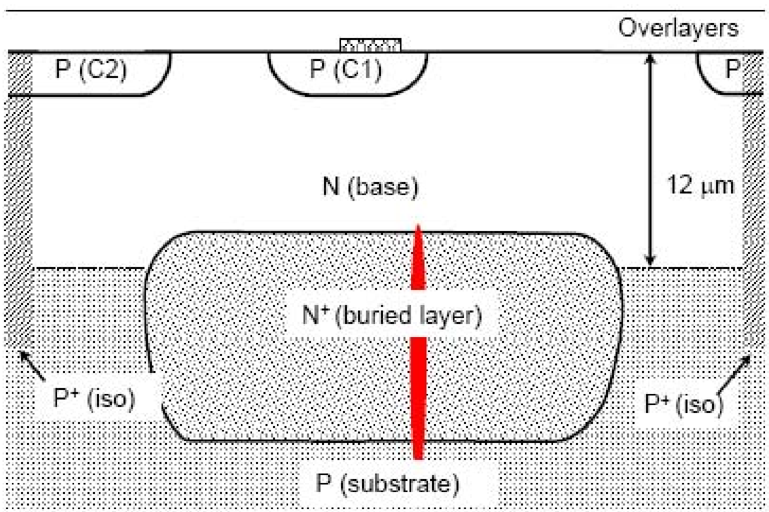

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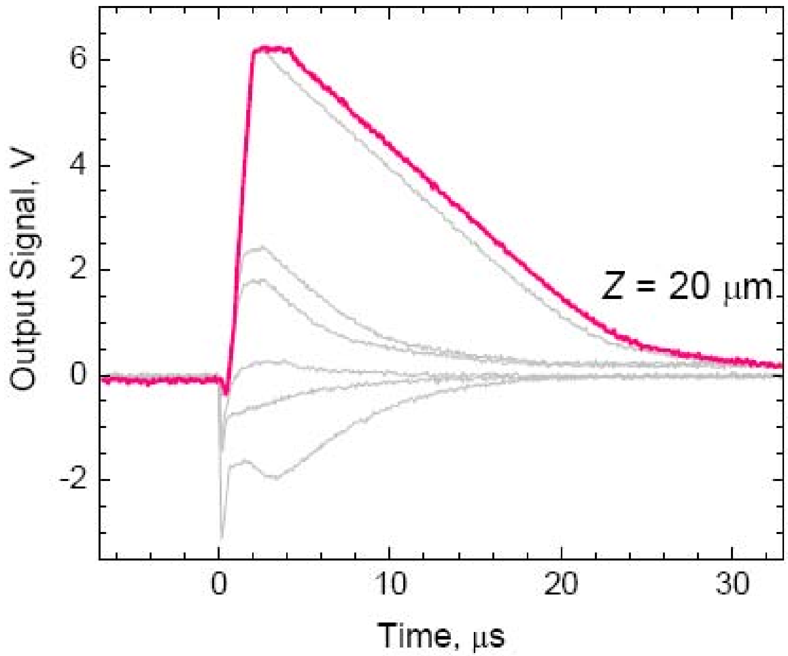

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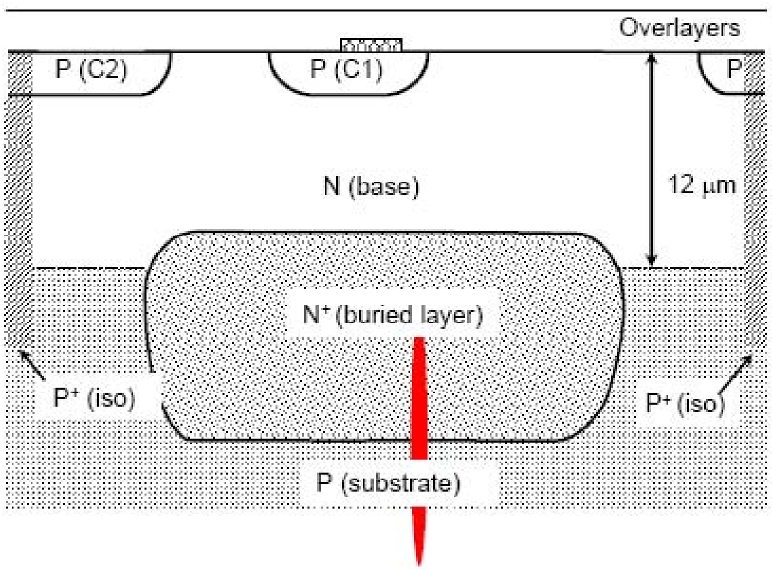

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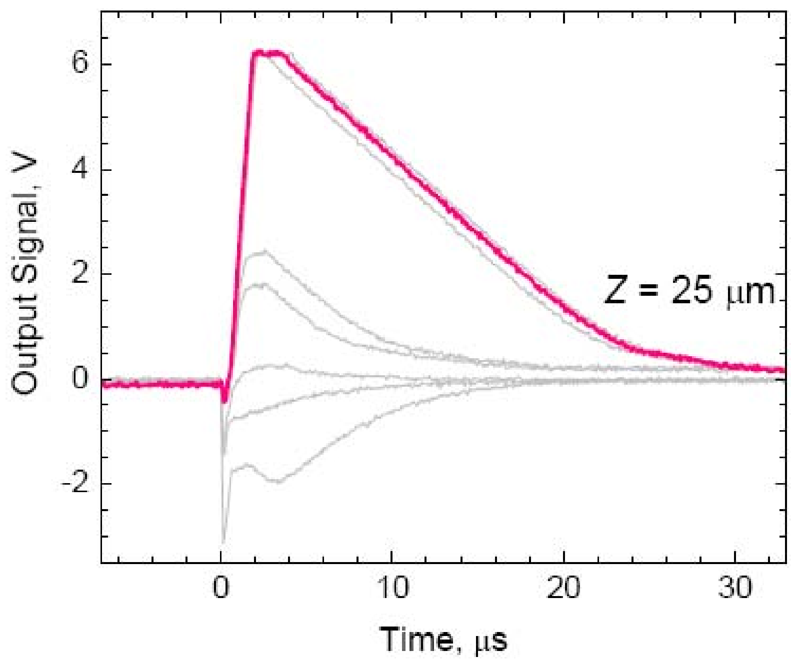

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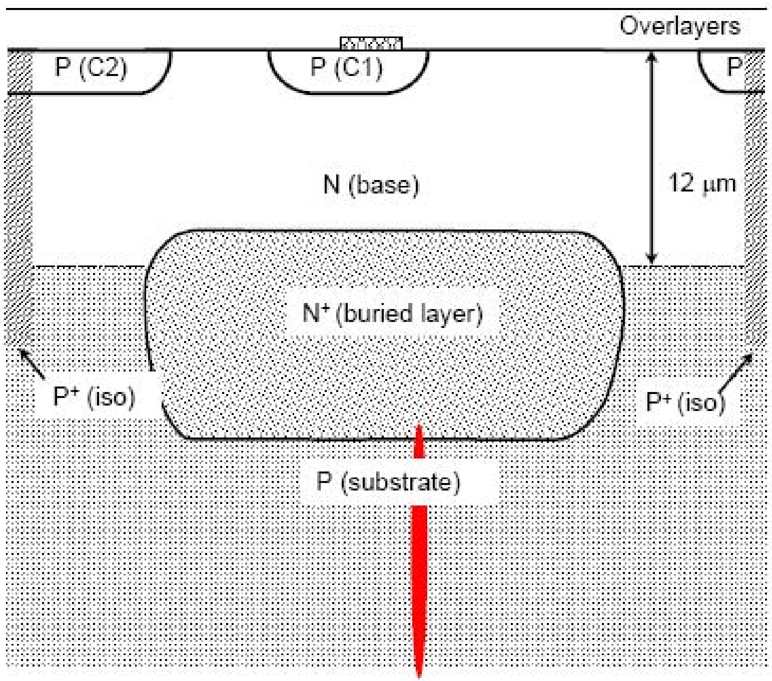

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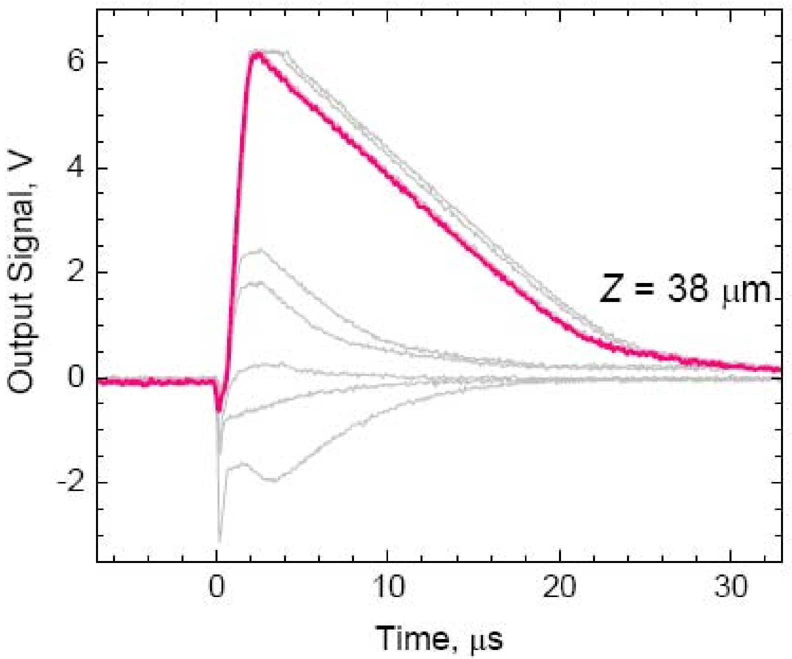

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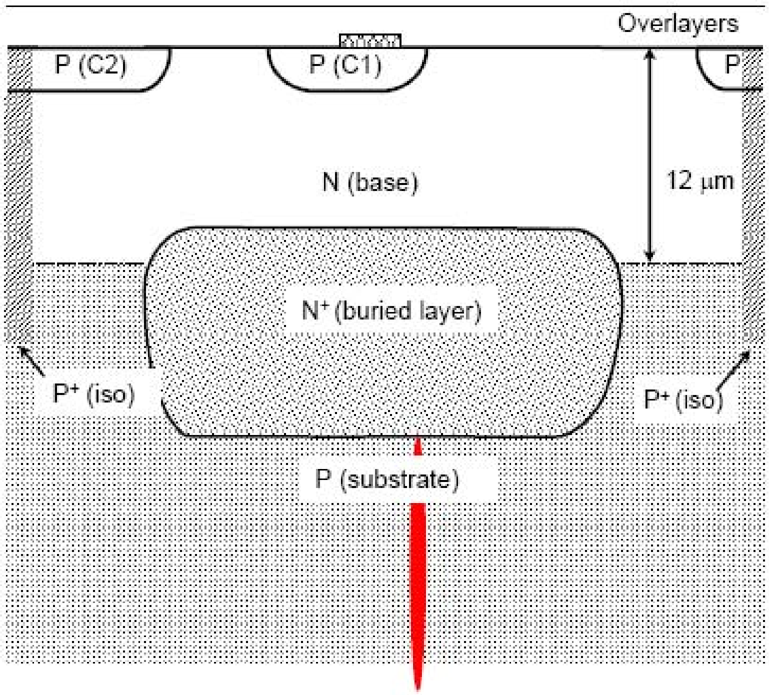

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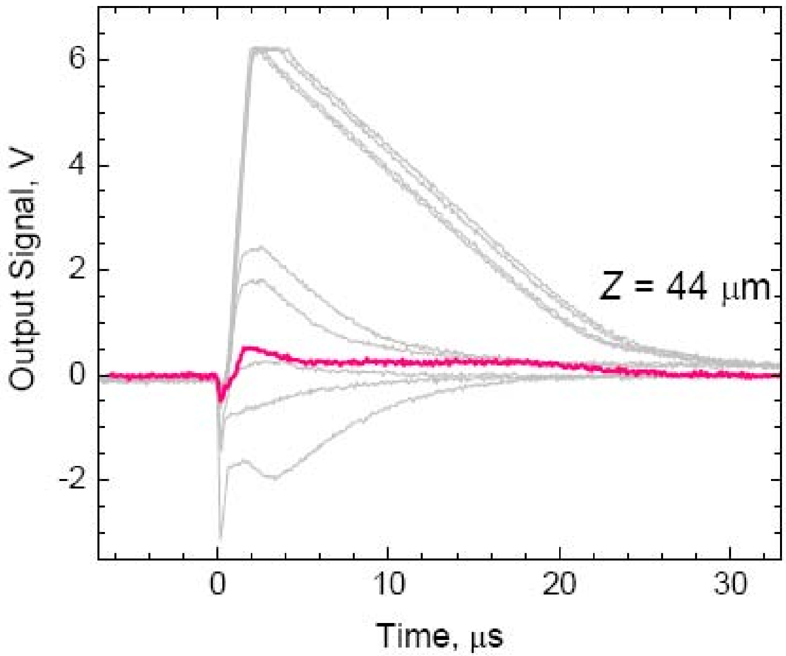

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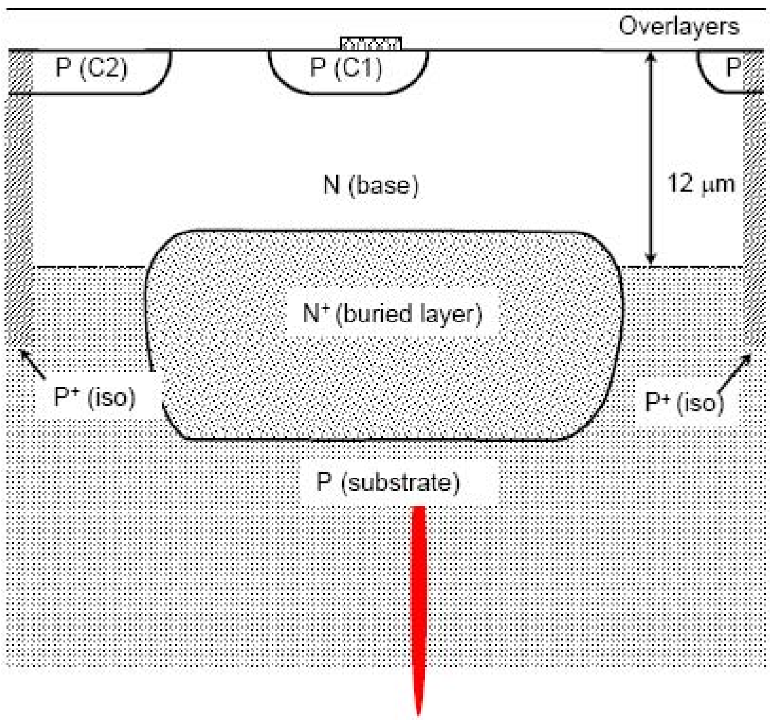

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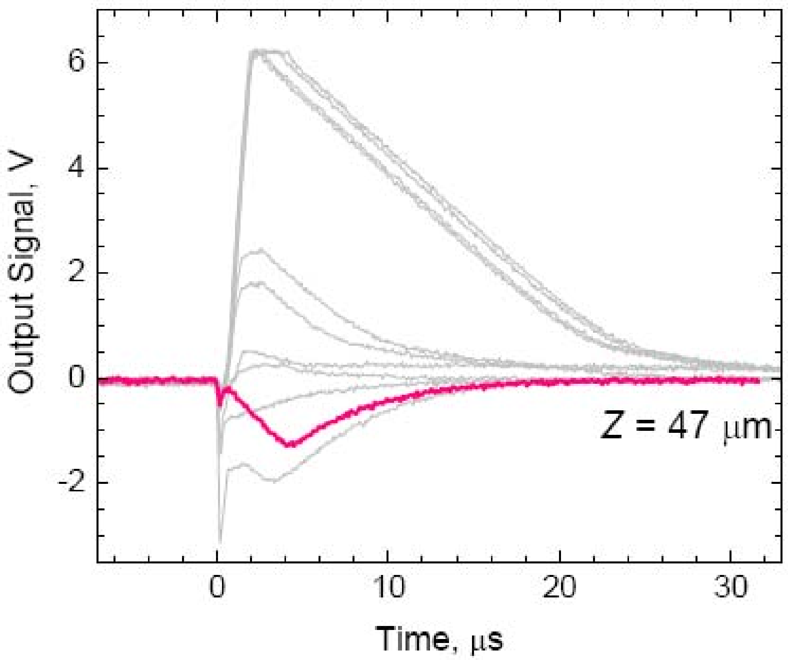

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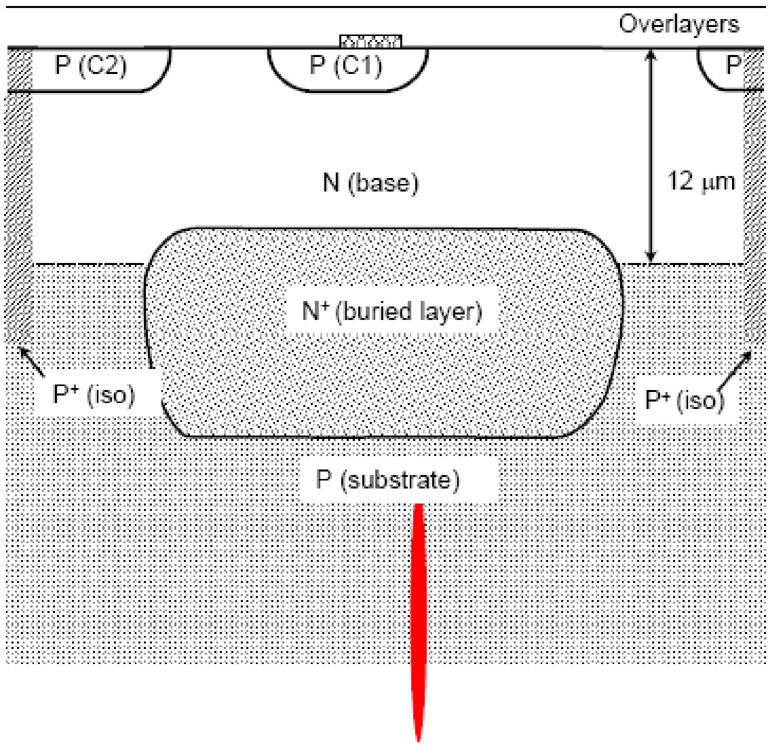

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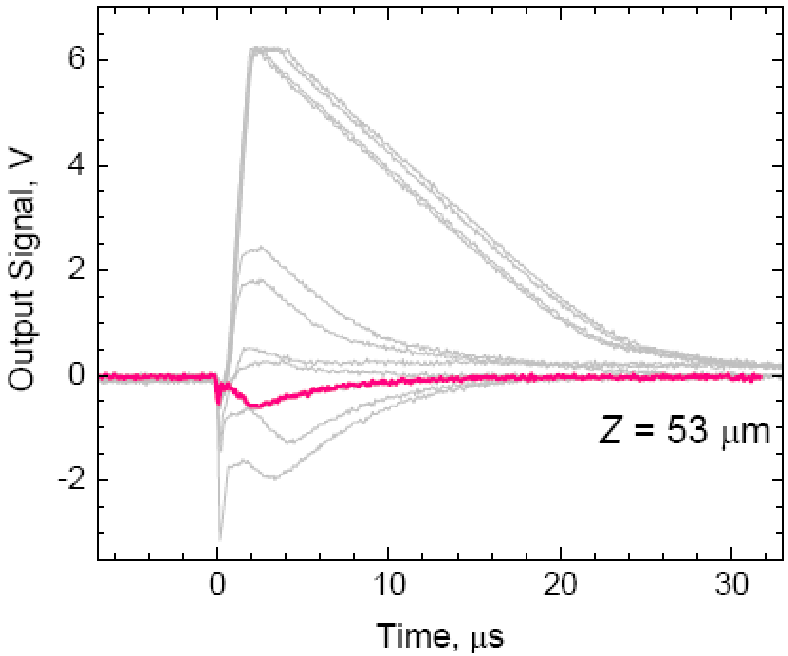

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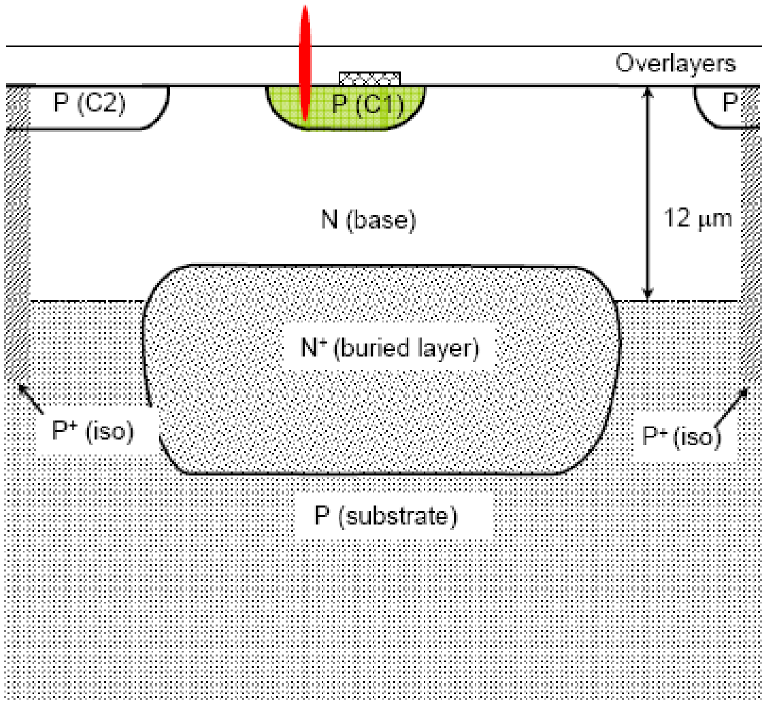
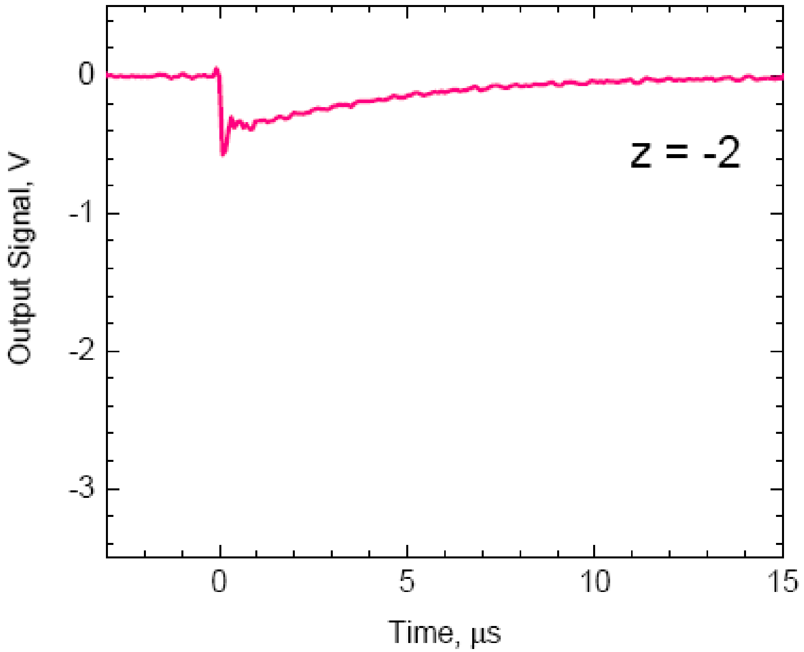
SET event rate calculation in analog ICs Thickness of sensitive volume



Low power measurements



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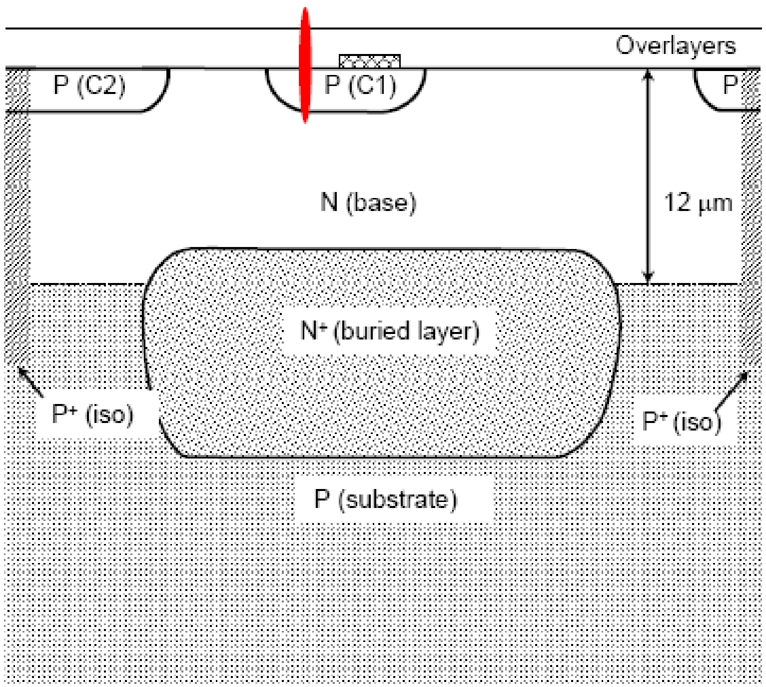

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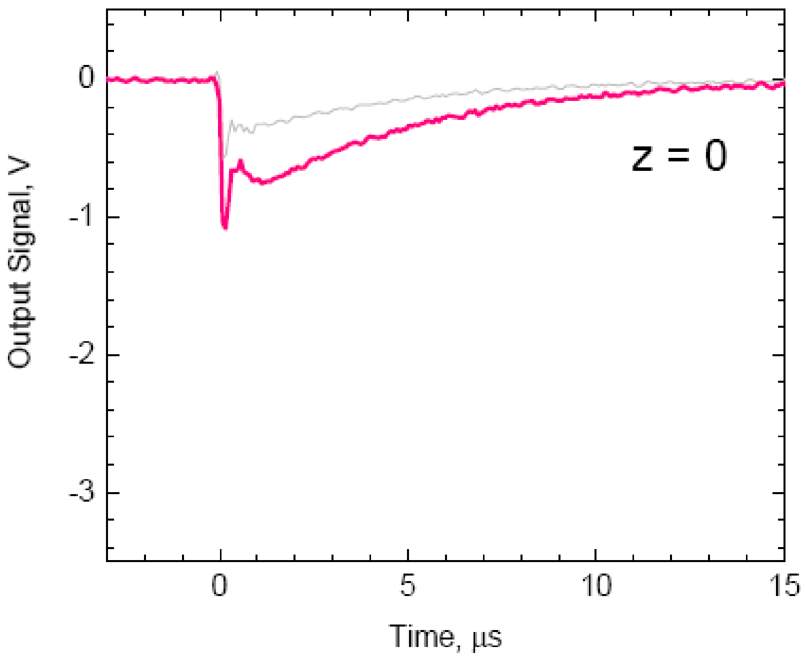

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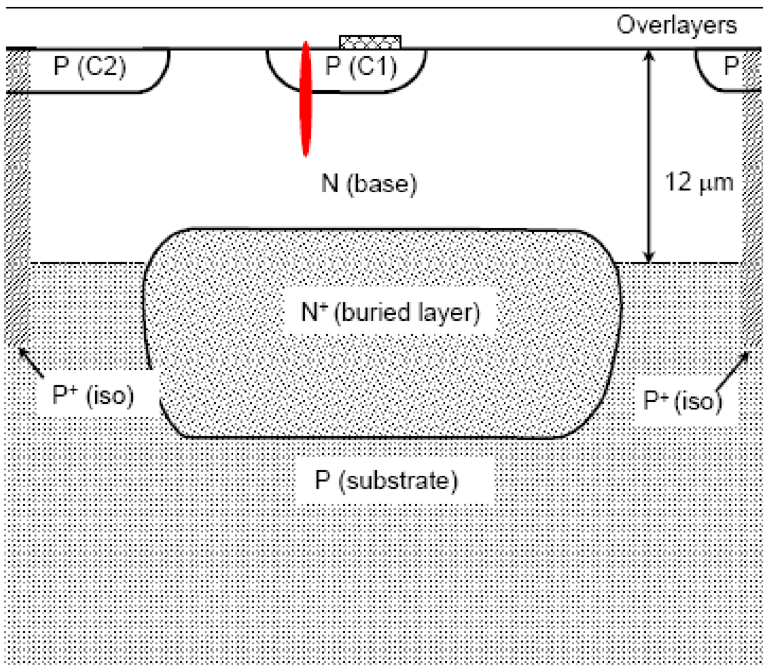

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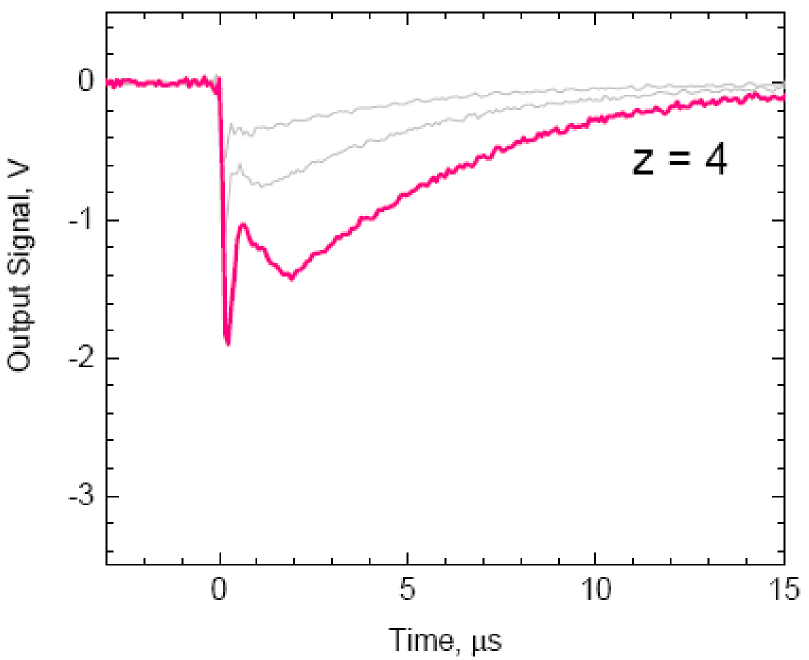

After McMorrow, SERESSA 2006

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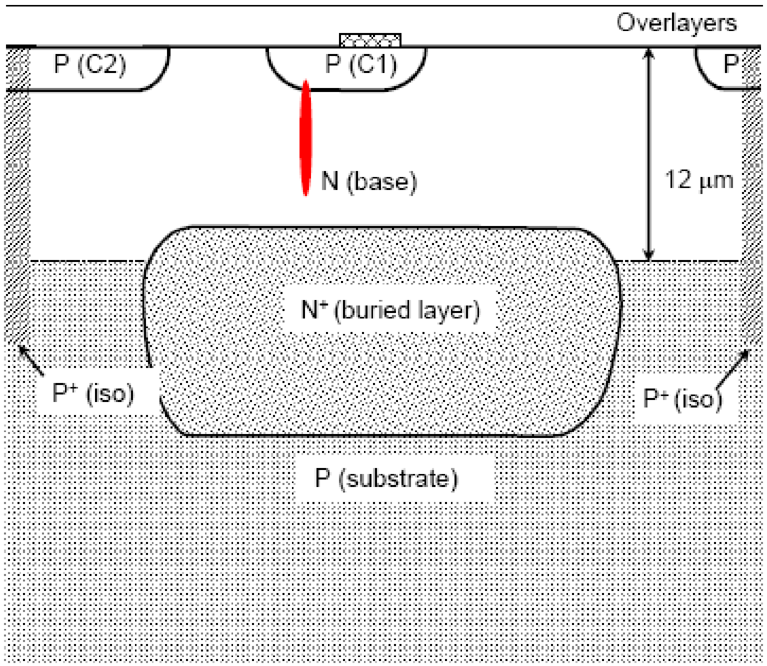
Thickness of sensitive volume



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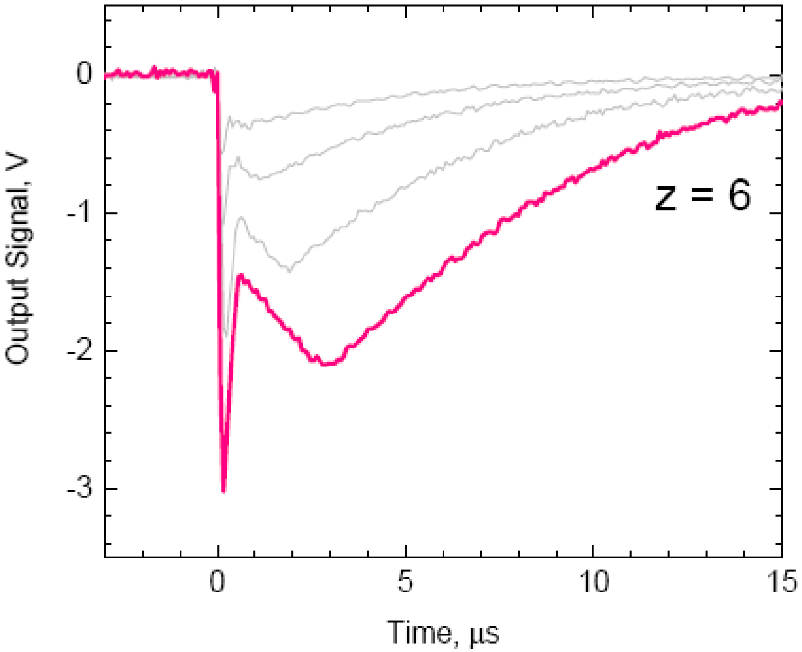

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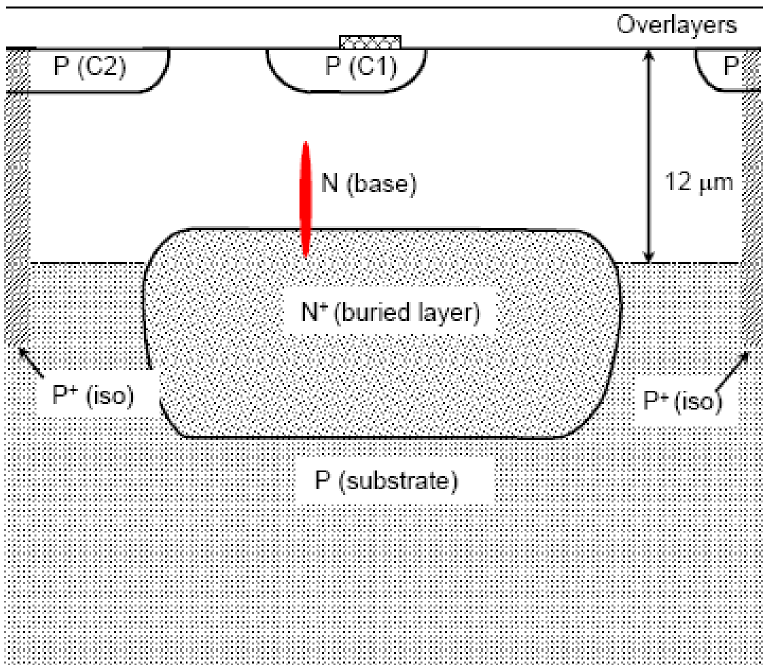

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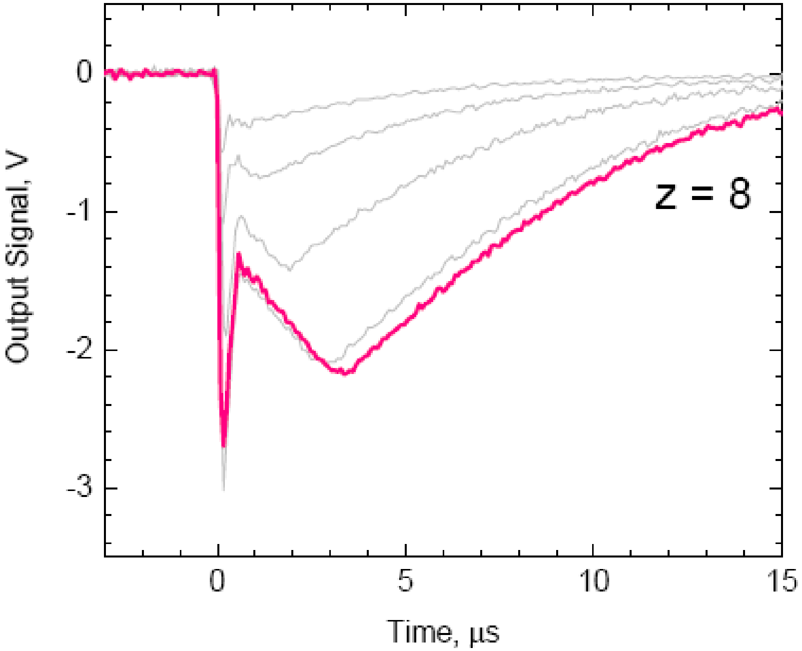

After McMorrow, SERESSA 2006

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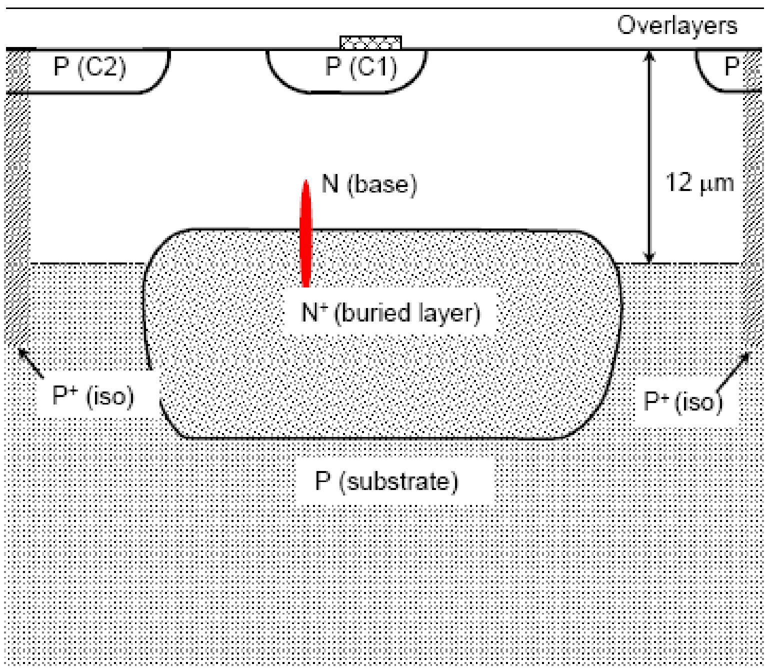

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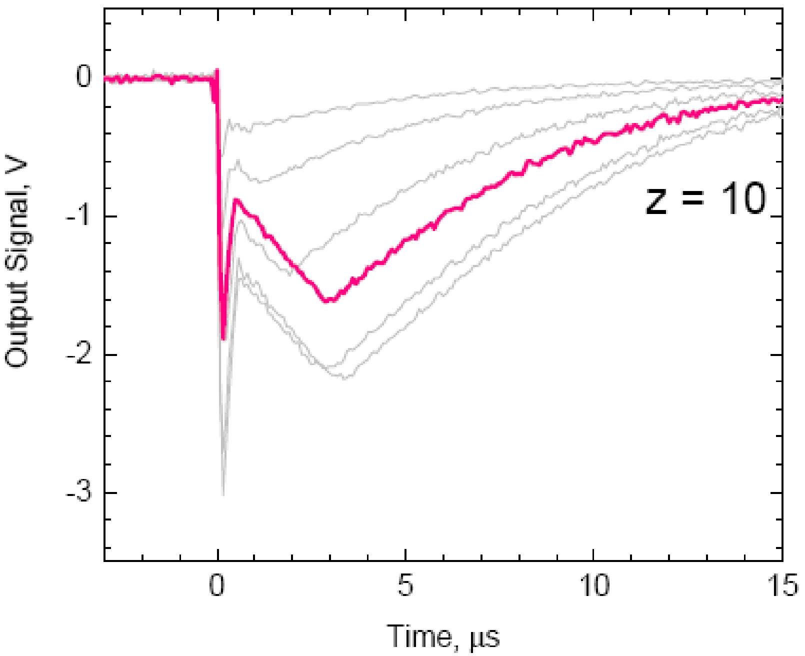

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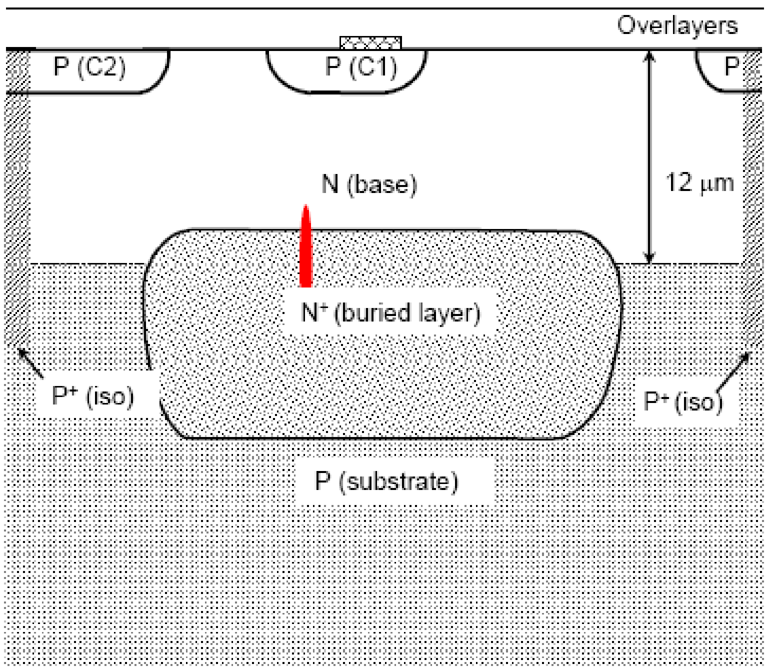

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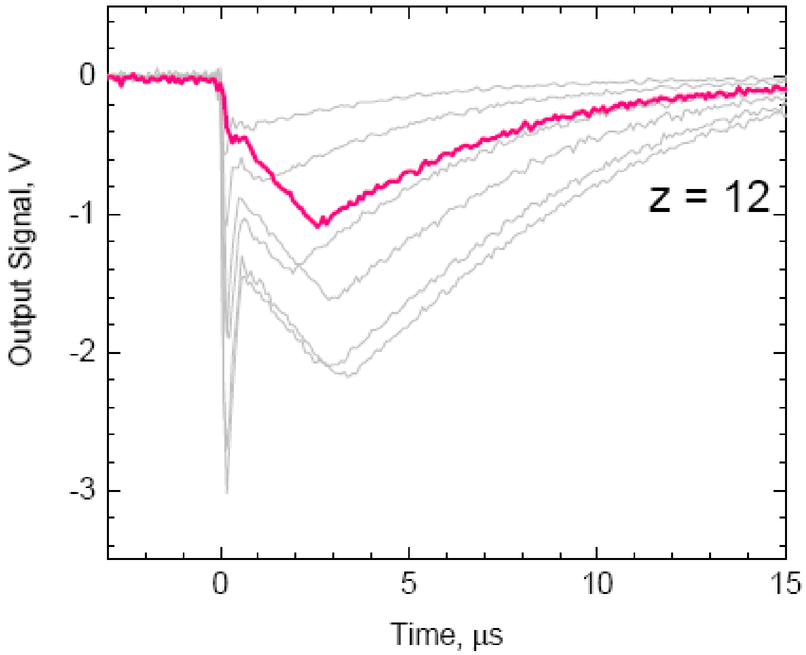

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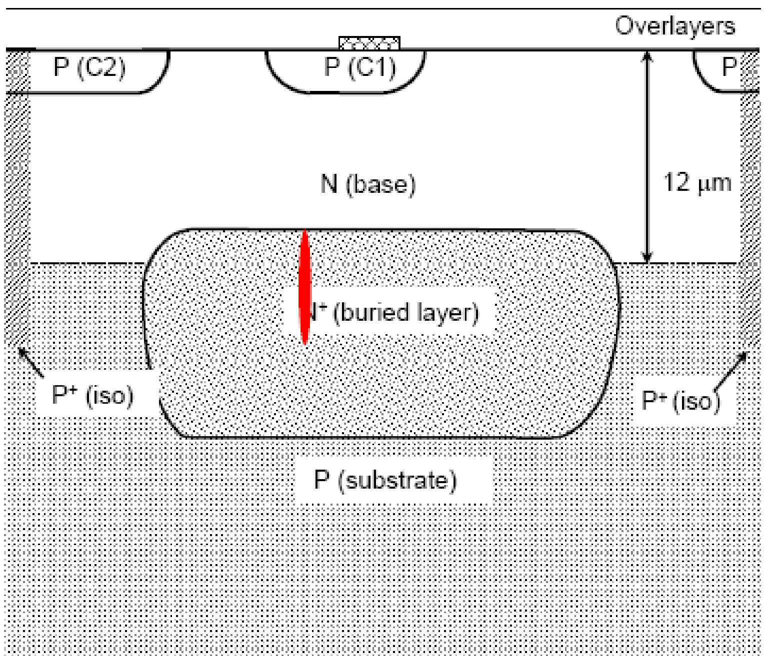

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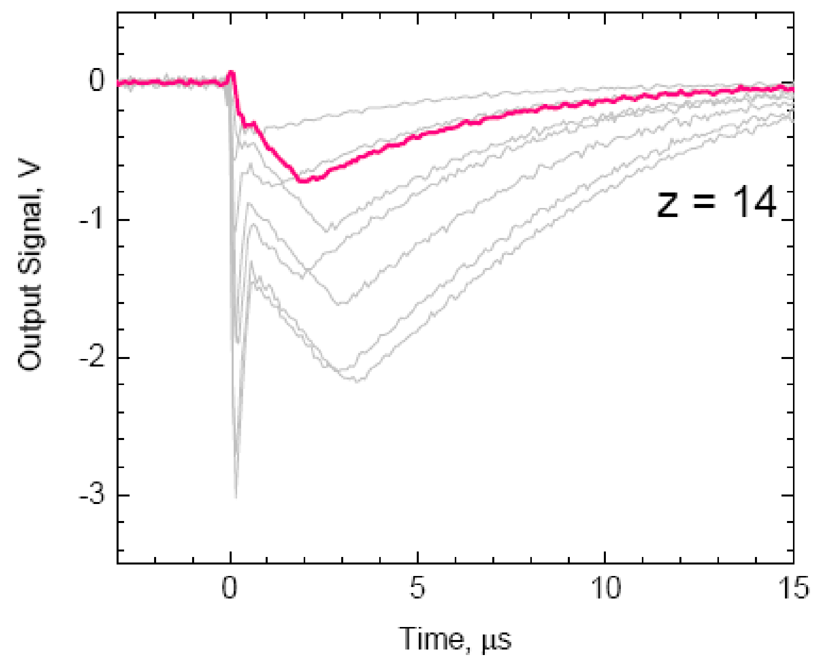

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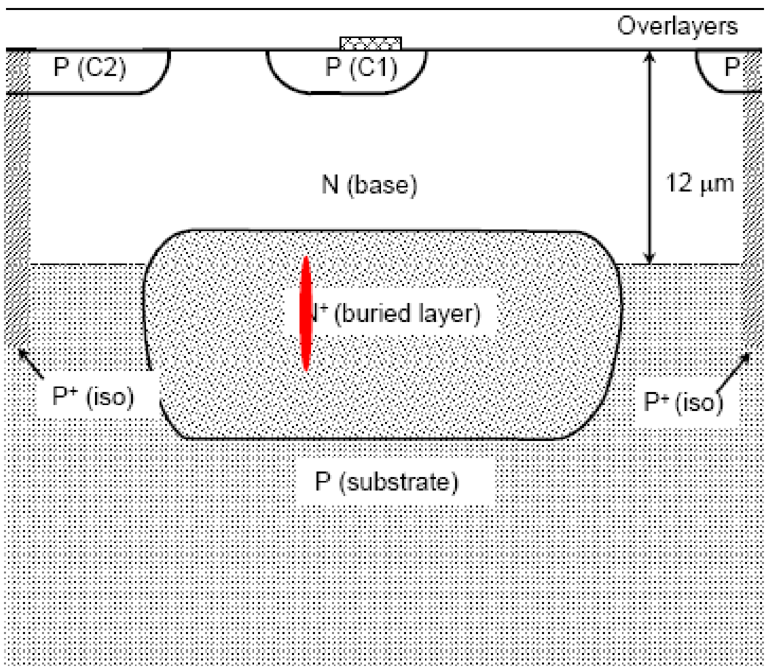

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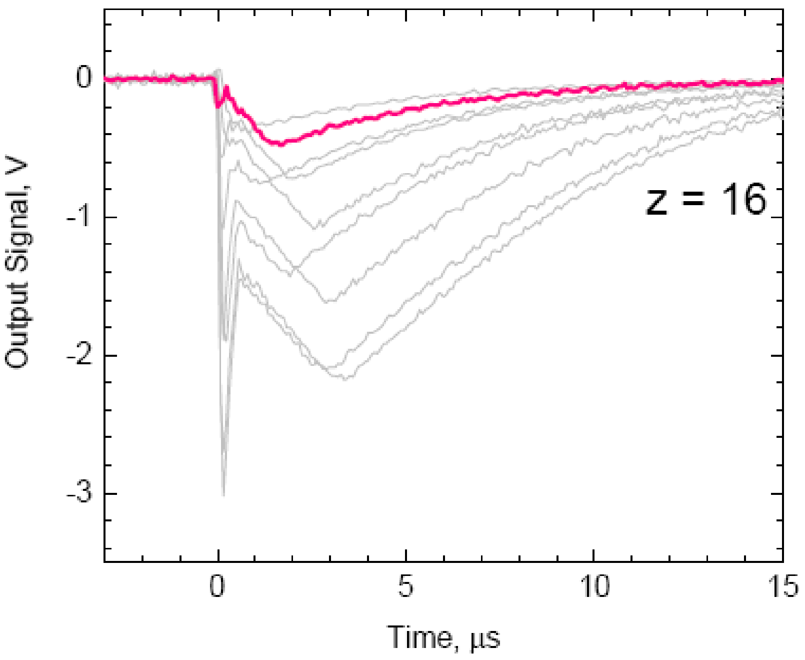

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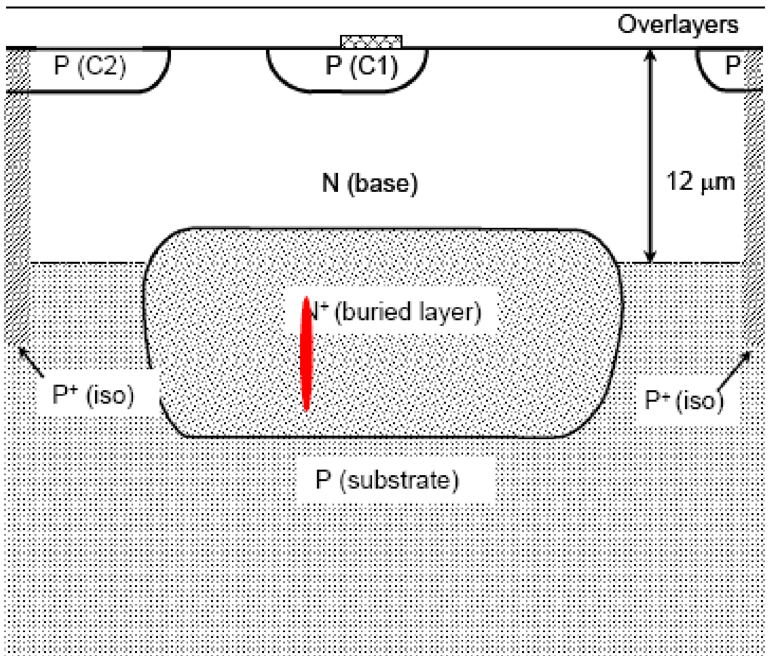

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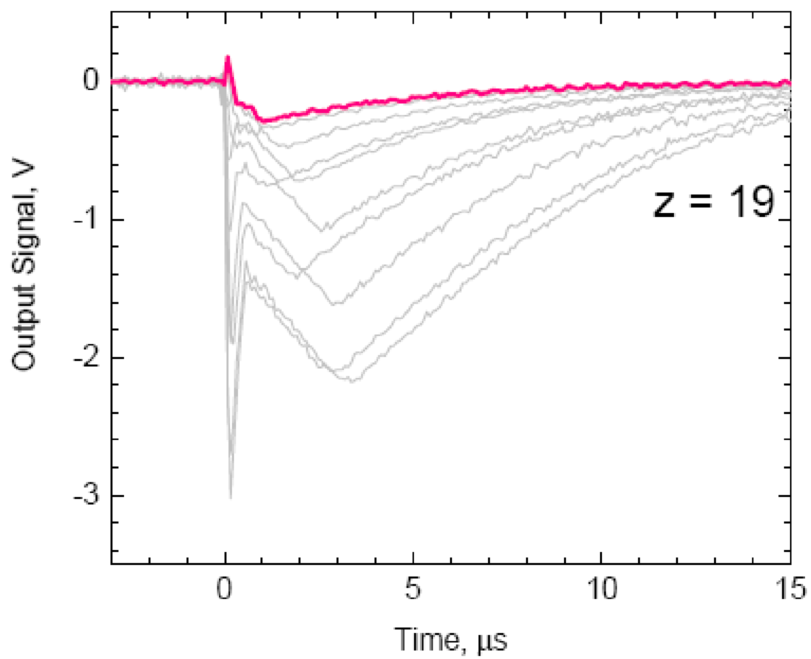

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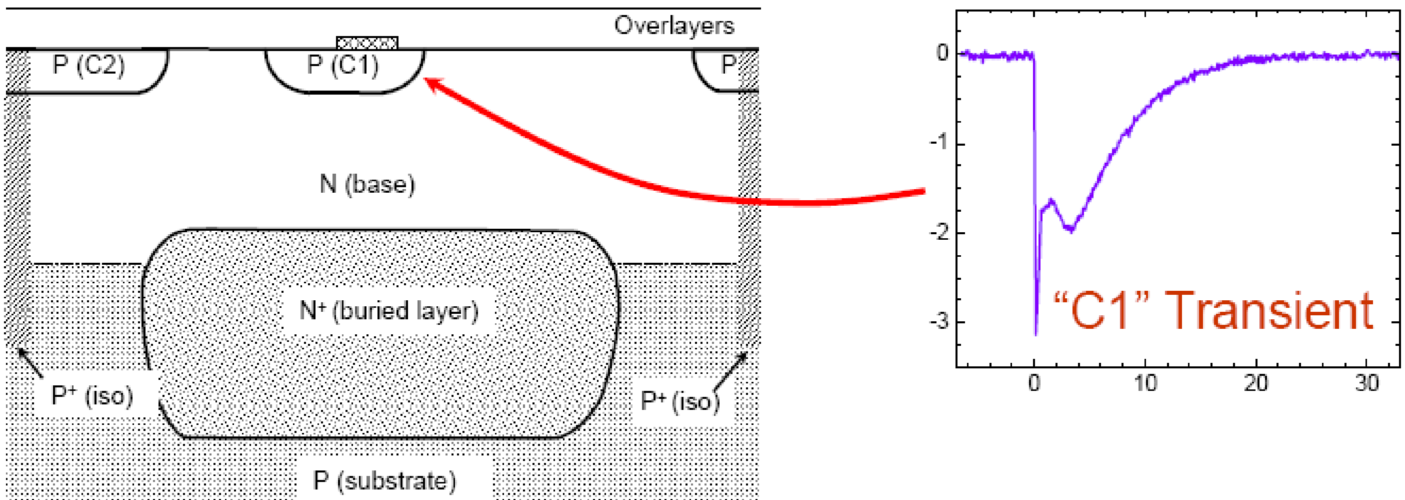
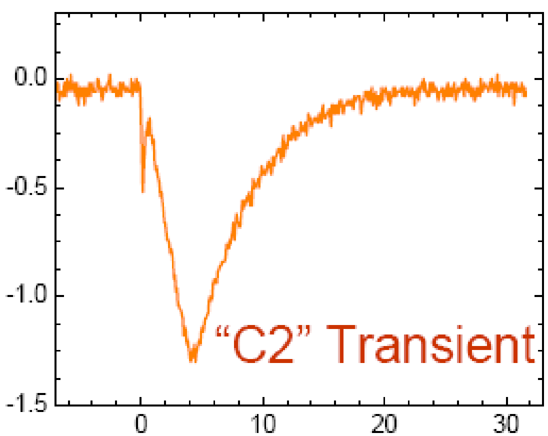
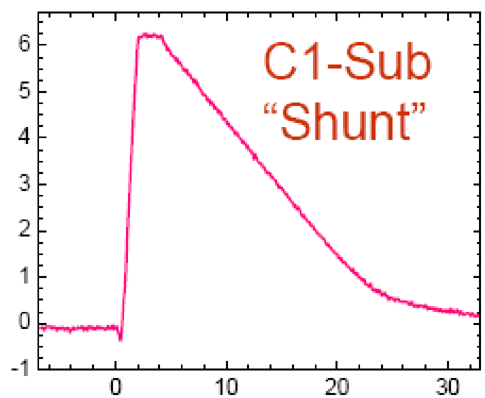
Z Dependence

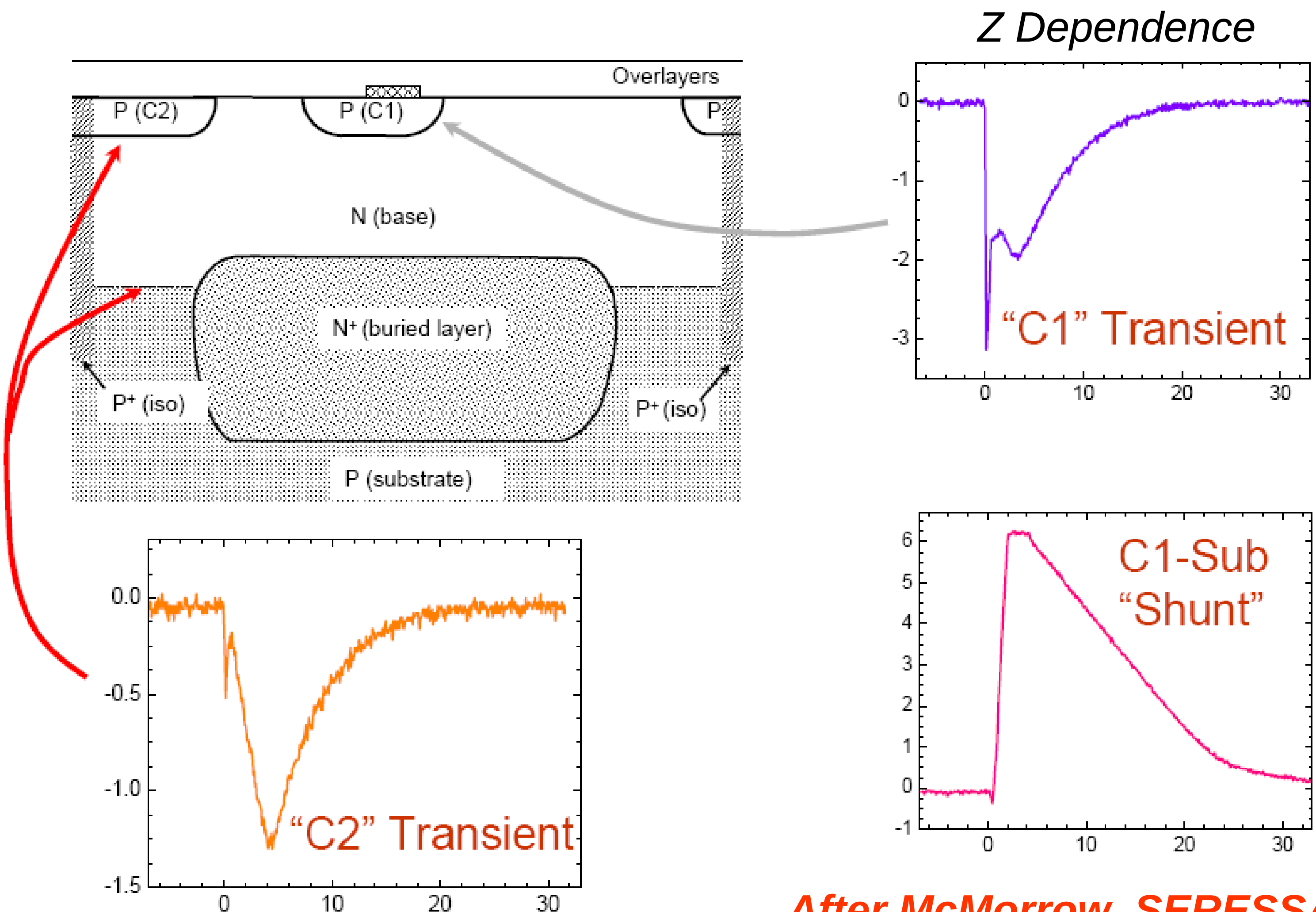






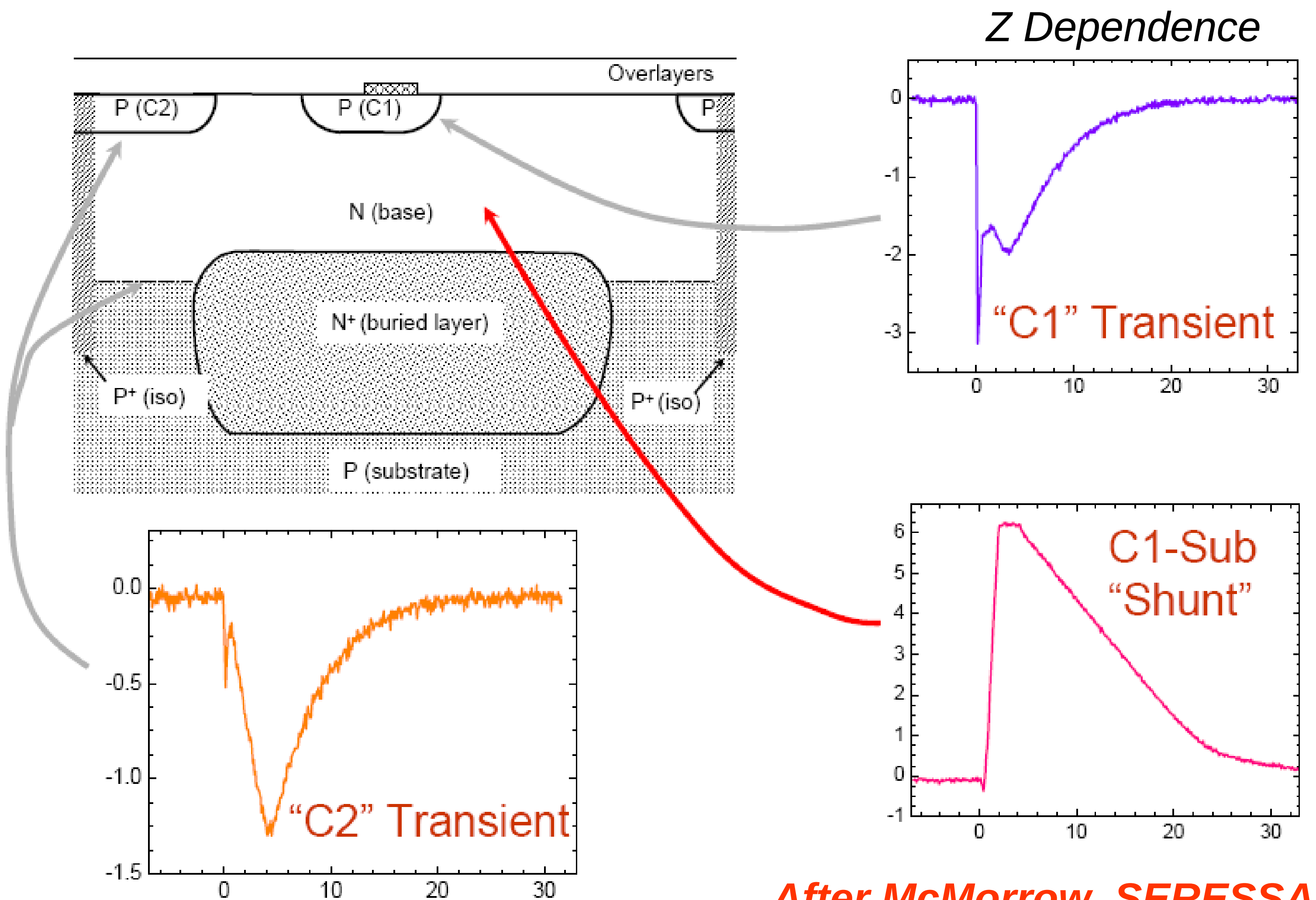
After McMorrow, SERESSA 2006

SET event rate calculation in analog ICs
Thickness of sensitive volume



After McMorrow, SERESSA 2006

SET event rate calculation in analog ICs
Thickness of sensitive volume



After McMorrow, SERESSA 2006

SET event rate calculation

- Example, LM139
  - Effect of thickness of sensitive volume

Sensitive Volume Thickness (μm)	Rate of GCR induced SET (CREME96 solmin) #/comparator-day	Rate of SPE induced SET (CREME96 worst day) #/comparator-day
2	4.99E-03	1.63E+00
5	4.88E-03	9.4E-01
10	4.69E-03	5.1E-01
15	4.51E-03	3.2E-01
20	4.34E-03	2.1E-01
30	4.02E-03	1.3E-01
40	3.7E-03	1.2E-01
60	3.01E-03	9.83E-02

Flight data, SOHO

Module	Device	Observed in Flight (5 years)	Predicted
VIRGO	PM139	5	5
LASCO	UC1707	0	~0.1
ACU	UC1707	5	3

- *1 sensitive volume*
- *thickness = 2 μm*

From Harboe-Sorensen, RADECS 1999 & 2001 Proceedings

Flight data, MAP

- **Flight Data**:
  - One anomaly during November 5 solar event
  - One anomaly in 2 years
- **Predictions**: PM139

Sensitive volume thickness (μm)	GCR SET rate CREME 96 solmax (#/comparator-year)	Solar Event SET rate CREME 96, worst day (#/comparator-day)
10	6.57E-01	5.1E-01
15	6.21E-01	3.0E-01
20	5.84E-01	1.8E-01
30	5.48E-01	6.5E-02
40	4.75E-01	4.4E-02
60	3.61E-01	3.4E-02

After POIVEY, RADECS 2002

Conclusion

- Most SET RHA issues are related with the bounding of part response.
- An accurate characterization allows an accurate analysis.
- Low confidence shall be given to SET rates predictions.
- Your comments are welcome.

Backup slides

Ronan Marec, et al
RADECS 2001