SiC Gen 2.0: Softer in Switching, Rugged in Radiation

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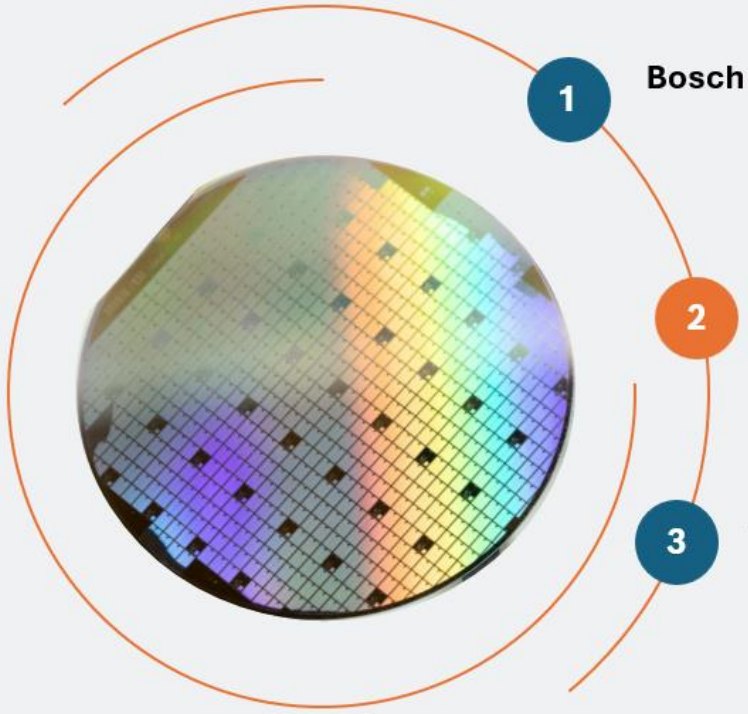
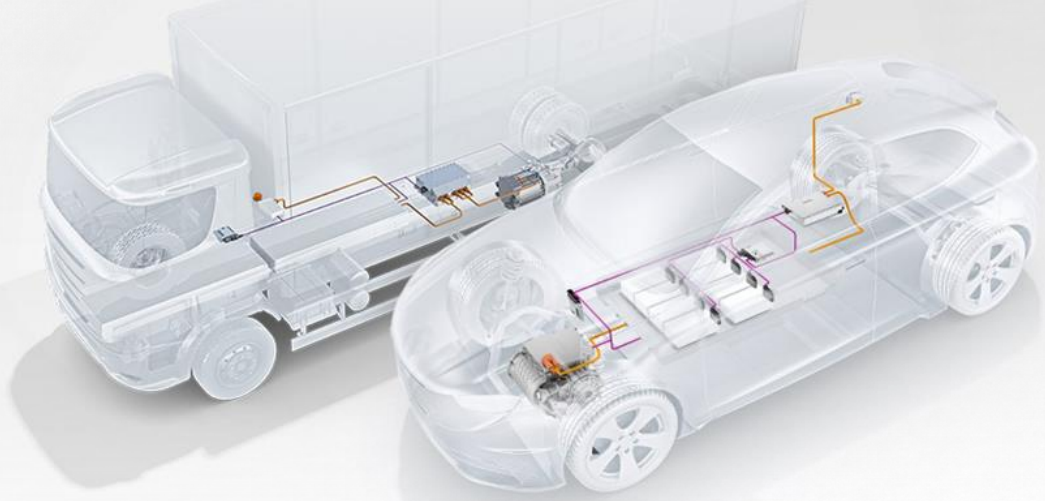
BOSCH

SiC MOSFET Gen 2.0
Agenda



1. Bosch SiC-Roadmap
2. SiC Gen 2.0: Optimized for Switching
3. SiC Gen 2.0: Cosmic Radiation Ruggedness

From silicon carbide semiconductors to electric drive systems



Bosch electrifies all vehicle classes and offers all integration levels

- From SiC semiconductors and components to electric drive systems and charging solutions
- From systems engineering to manufacturing
- From passenger cars to commercial vehicles worldwide

Bosch electric drive portfolio

Energy-efficient semiconductors

SiC power semiconductors

→

Subcomponents

SiC power modules on cooler, stator, and rotor

→

Components

Inverter, DC/DC converter, and electric motor

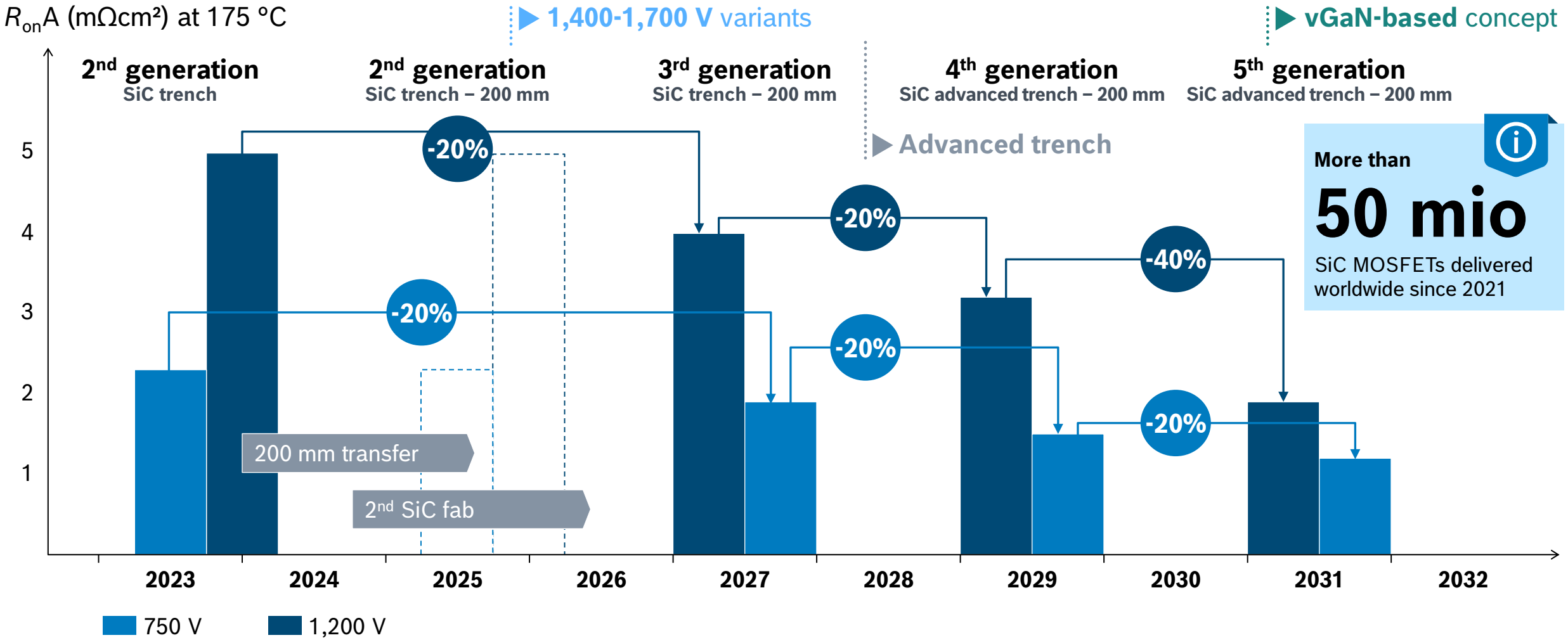
→

System solutions

Charger-converter

eAxle systems

SiC power MOSFETs from Bosch
Roadmap



Technology insights
More than just a switch

Deep p-implantation: gate shielding + short-circuit ruggedness

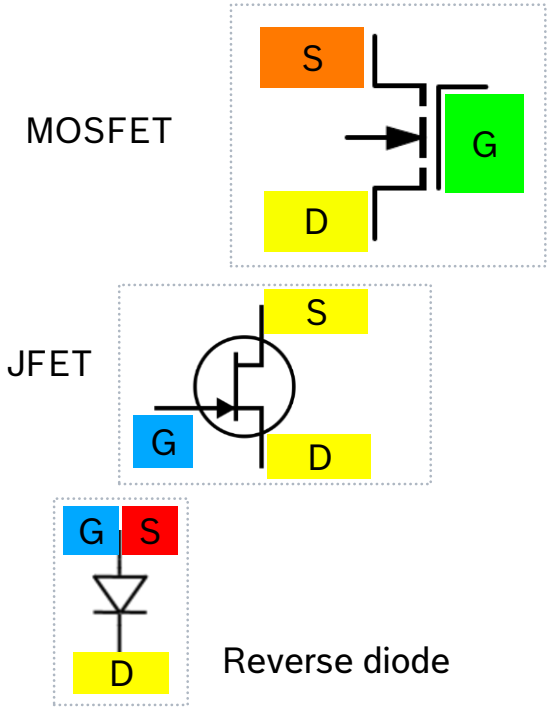
1 Better trade-off $R_{on}A$ and short-circuit

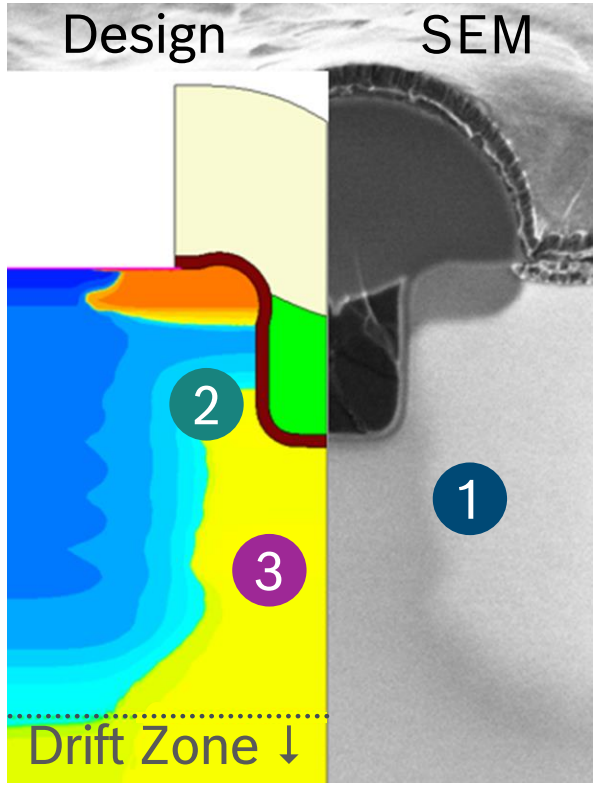
Optimized capacitance from C_{GD} ,$C_{GS,}$ C_{DS}

2 Robust switching, parasitic turn-on immunity and self-excited oscillation

Improved uniformity of JFET region

3 Improvement of $R_{on}A$ tolerance

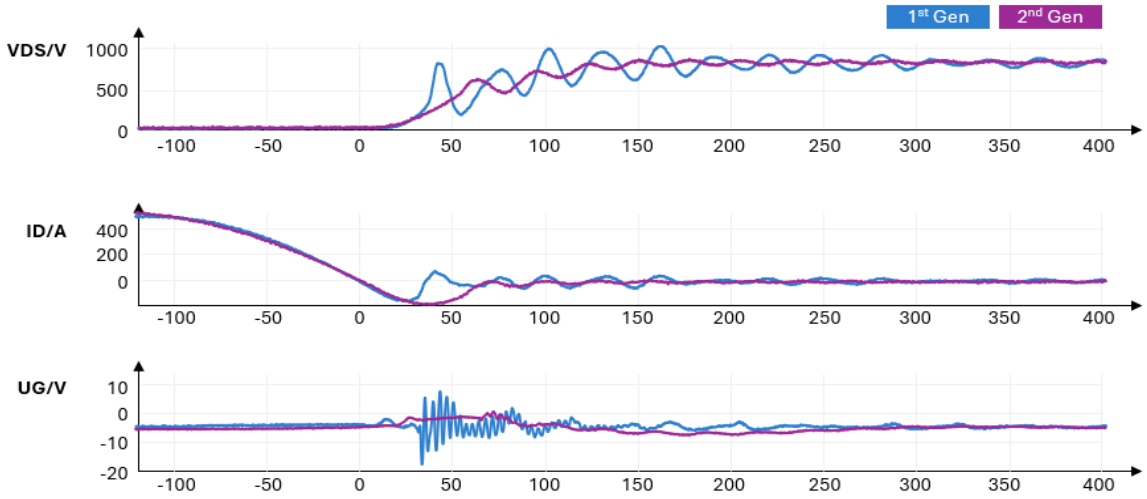




Holistic improvement of all key design elements for best static and dynamic performance

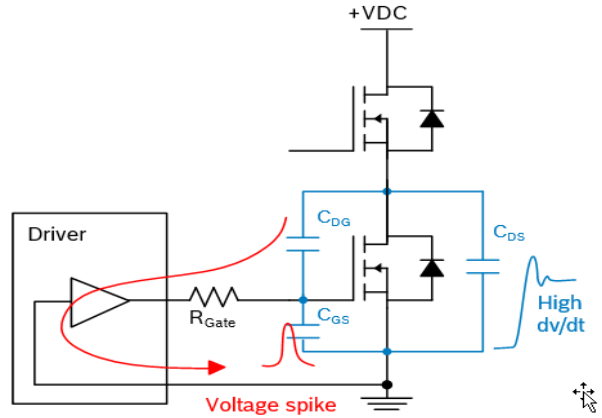
Softer switching
SiC Gen 2.0 switching behavior

Comparison 1st generation to 2nd generation switching during passive turn-off



SiC Gen 2.0 ensures PTO robustness over the temperature range:

- Better Q_{GD} / Q_{GS} (Miller Ratio)
- $V_{th,min}$ >3 V @ 25° C



Parasitic turn-on immunity
High immunity against parasitic turn-on by tuning of Miller ratio

Diode
Soft recovery over complete temperature range

Switching control
Very good controllability of maximum dv/dt

Clean switching
Low ringing ensured for SiC gen 2.0

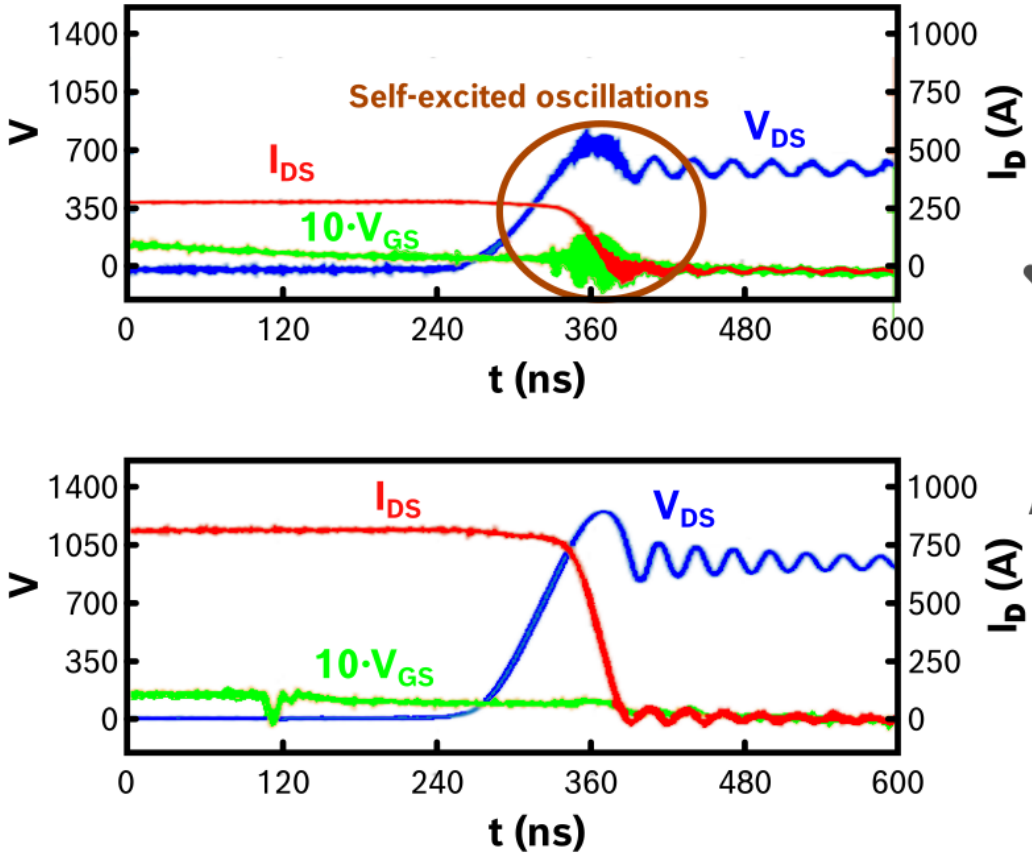
2nd generation with optimized switching behavior for EV inverter over low and high temperature range

Softer Switching
Self-excited oscillations

⚠ **Risk:** self-excited oscillations

Main factor on chip side:
C_{DS}/C_{GD} ratio
→ the smaller the better

Novel SiC architectures feature **lower CGD** due to their higher integration depth
→ **new trade-off** to be considered



Advanced AIT Power Module

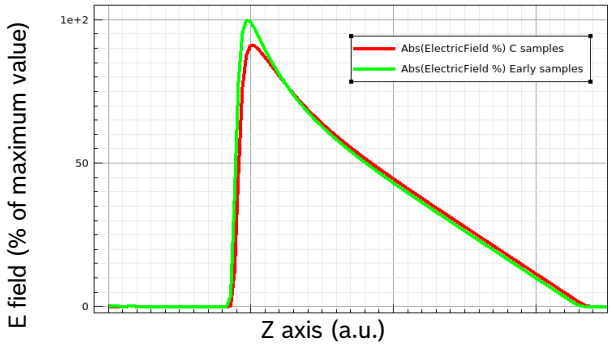
Considering the module during chip design becomes even more important with future SiC generations

Cosmic Radiation
Optimization of the Electric Field [Sc23, Sy24, Ak19]

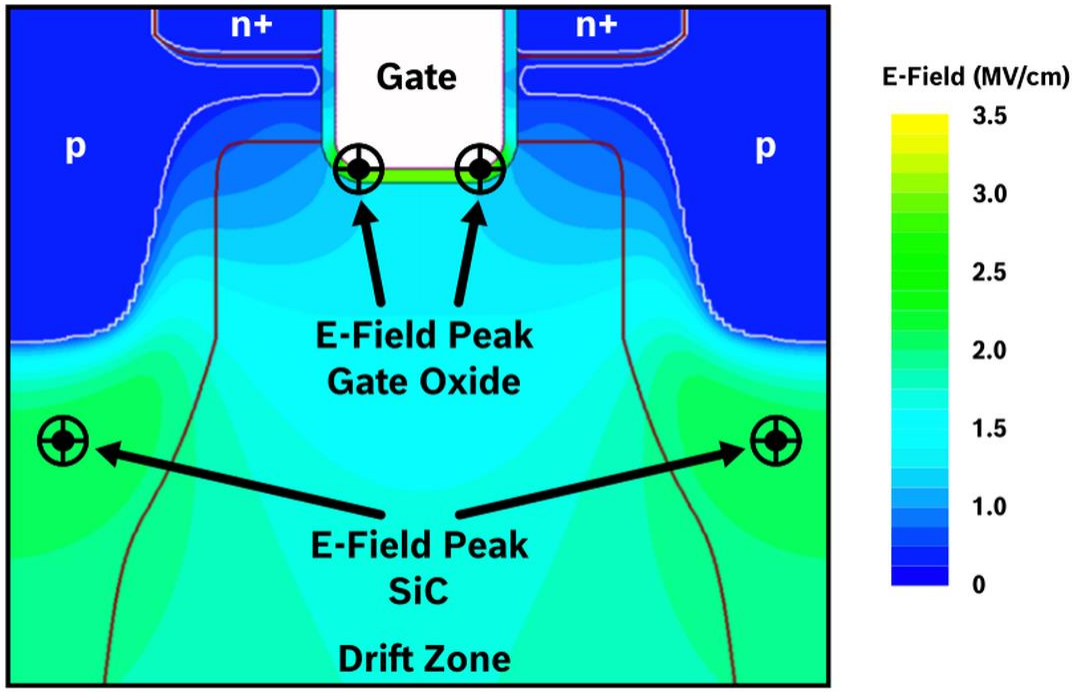
- Regions with high electric field are critical:
  - Traditional Approach: Increased V_{BVDSS} increases $R_{DS,ON}$
  - Local Failure Rate [Ak19]: P_{lf}

$$P_{\mathrm{lf}}(E(x)) = v_0 \exp\left(-\frac{E_{\mathrm{b}}}{E(x)}\right)$$

$$P_{\mathrm{f}} = \int_{\Omega} P_{\mathrm{lf}}(E)\mathrm{d}\Omega$$



Electric field distribution in Bosch SiC MOSFET



Electrical field shaping enables higher cosmic radiation ruggedness with better $R_{DS,ON}$

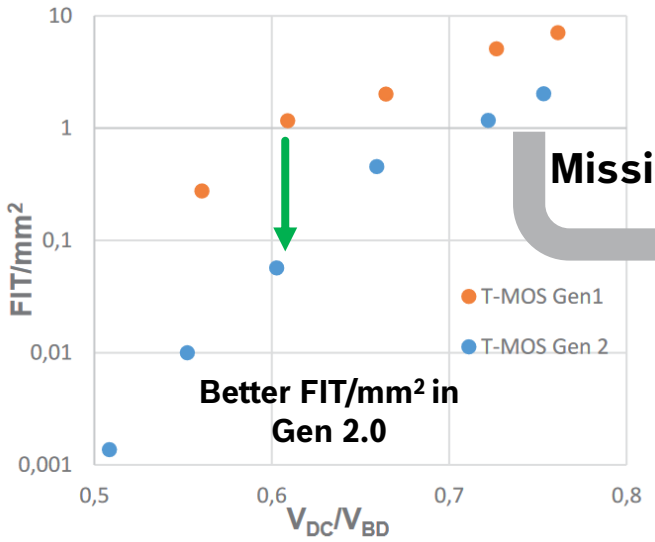
Cosmic Radiation
Comparison: SiC Gen 1.0 and Gen 2.0 [Sy24]

SiC Gen 1 to Gen 2.0: Measures

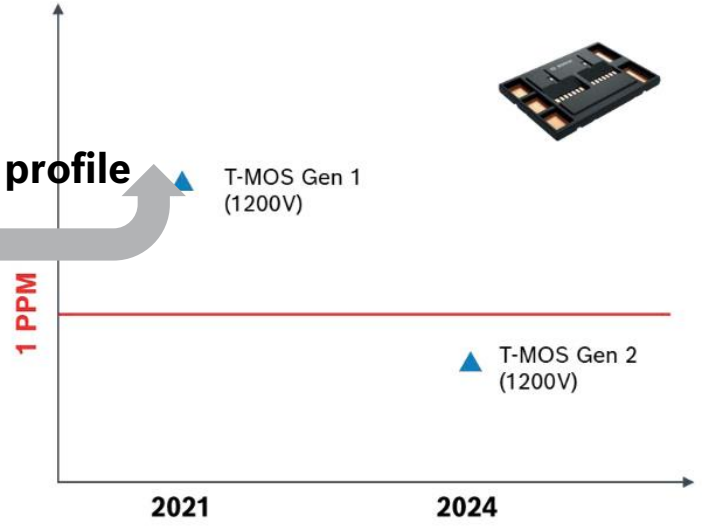
- Increase of Breakdown Voltage ~ 70 V
- E-Field-Shaping in Off-state with reduced E-Field-Peaks

- FIT-Rate, is derived from the accelerated test
- FIT-Rate from the cosmic radiation is convoluted with the mission profile and translated into module ppm

Chip Cosmic Ray FIT Rate 1200 V



Module PPM rate



Bosch SiC Trench MOSFET ensures high robustness against cosmic rays

Conclusion and Takeaways

SiC Gen 2.0: Softer in Switching / Rugged in Radiation

Radiation Ruggedness

- Increased VBVDSS
- Reduction of the peak electric field
  - P+ plug geometry
- Optimization around the worst-case voltage values from the mission profile

Softer Switching

- Better high temperature diode behavior
- Better Miller ratio
- Hight threshold voltage
- Better self excited oscillation behavior

Bosch SiC Gen 2.0 ensures holistic optimization for inverter and charge application

Thank You!

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