Radiation Resistant Lighting

James Devine

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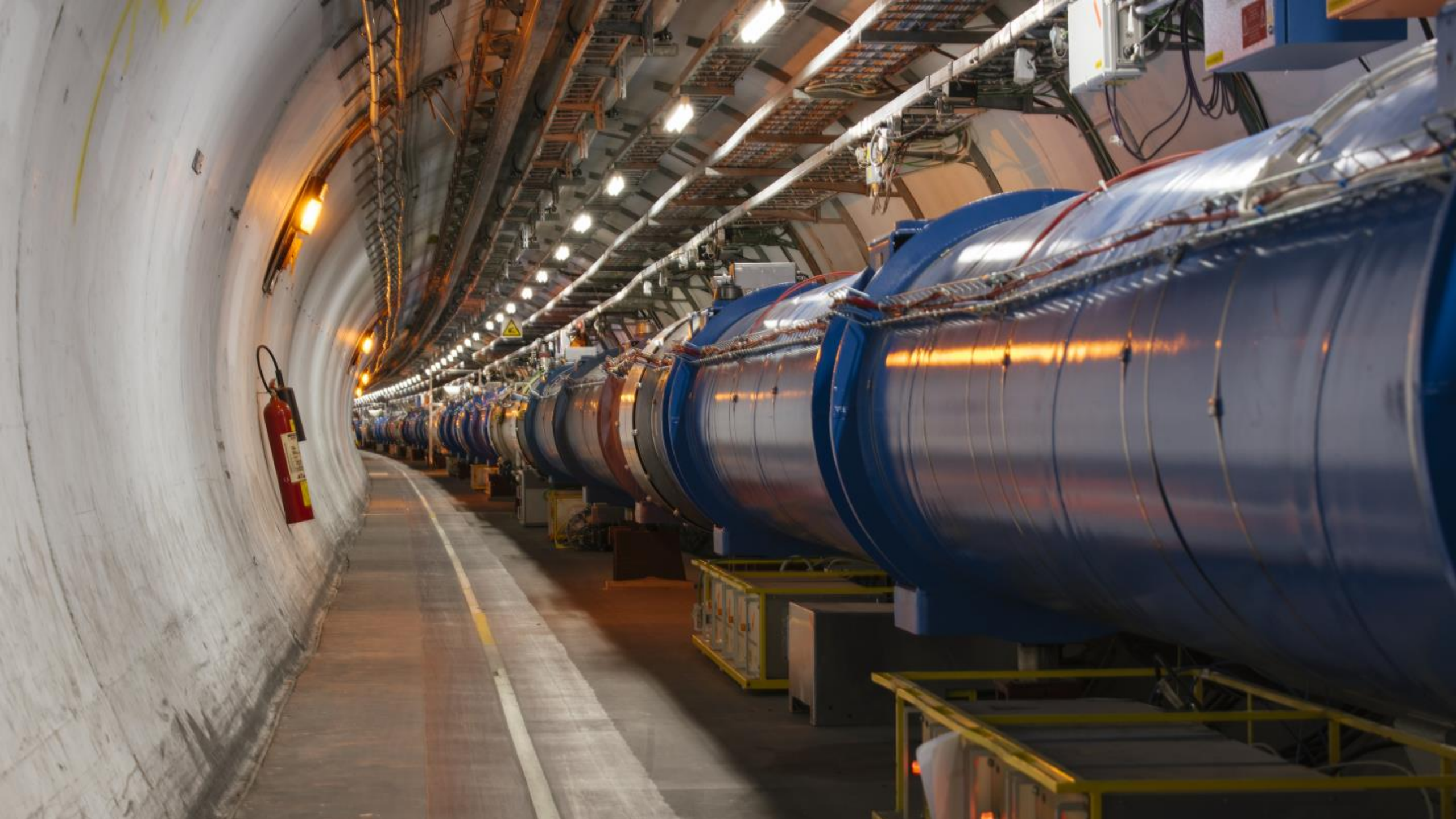
Development Drivers:

Fear of the dark!

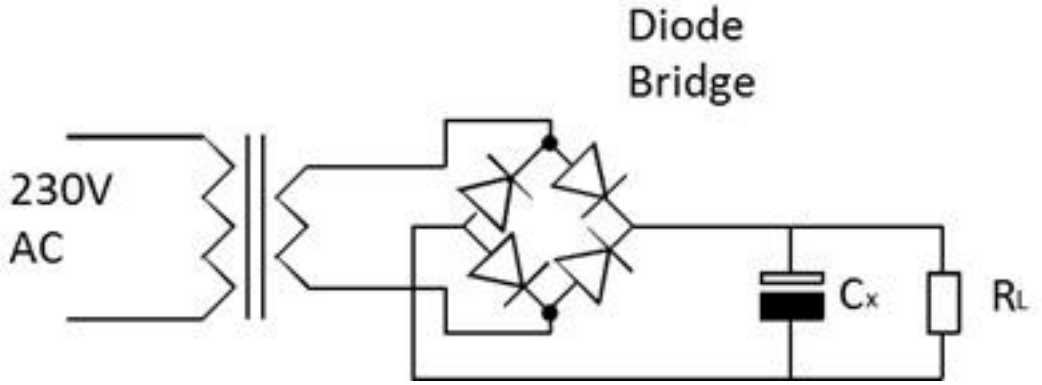
Obsolecence of existing technologies:

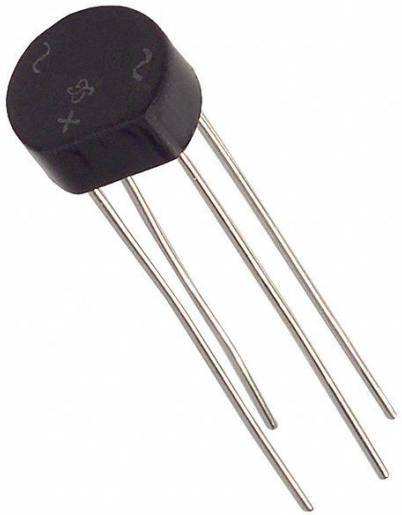
- Low pressure sodium lighting, SOX
- Fluorescent tubes & wire wound ballasts
- Xenon beacons

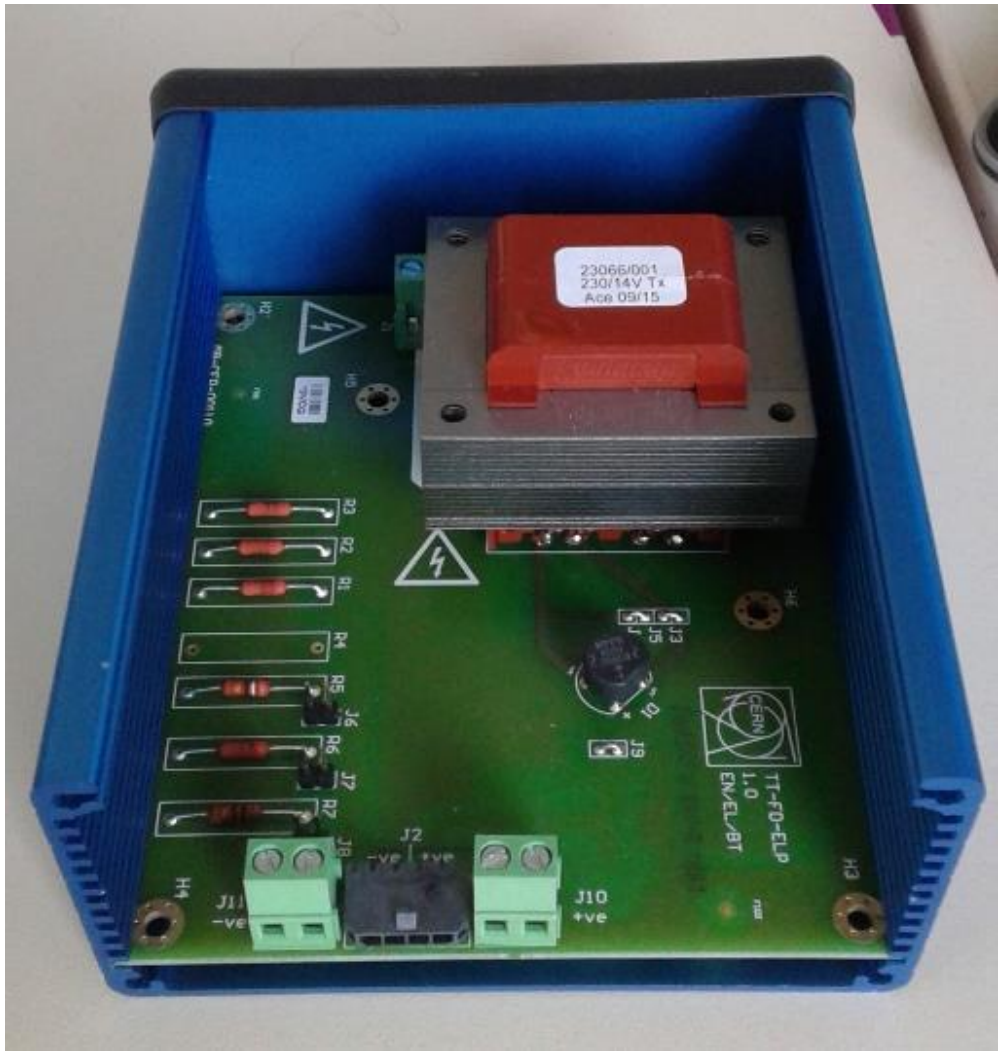
LED is the only commercial alternative.



Radiation hard Emergency lighting







Up to 7W maximum load.
Expected functionality up to 1kGy, mixed field.
(Limited by Si diodes)

Radiation hard
Conventional lighting

```
.tran 0 1000m 0 100u startup


.lib GIT_PGA26E19BA.lib


*$

.MODEL STPSC10H065D D
+ IS=510.14E-21 N=.94967 RS=54.909E-3 IKF=1.0000E3 CJO=483.36E-12 M=.44365
+ VJ=1.7167 ISR=55.766E-9 NR=2.8818 FC=0.5 TT=0 XTI=2 EG=3.26

*$

** True model Osram
*$
* LED = GW CSSRM2
* INFORMATION: TYP Vf BINNING, WITH TEMPERATURE BEHAVIOUR
* DATASHEET VERSION: V1.3
* LIB DATA: 2016-09-19
* AUTHOR: MARDIANA KHALID

.MODEL GW_CSSRM2_CM_typ_TRS D
+ IS=591.23E-21
+ N=2.5909
+ RS=0.1361
+ EG=3.0680
+ XTI=3
+ TRS1=-0.007082755
+ TRS2=0.000044048
+ CJO=1.0000E-12

*$
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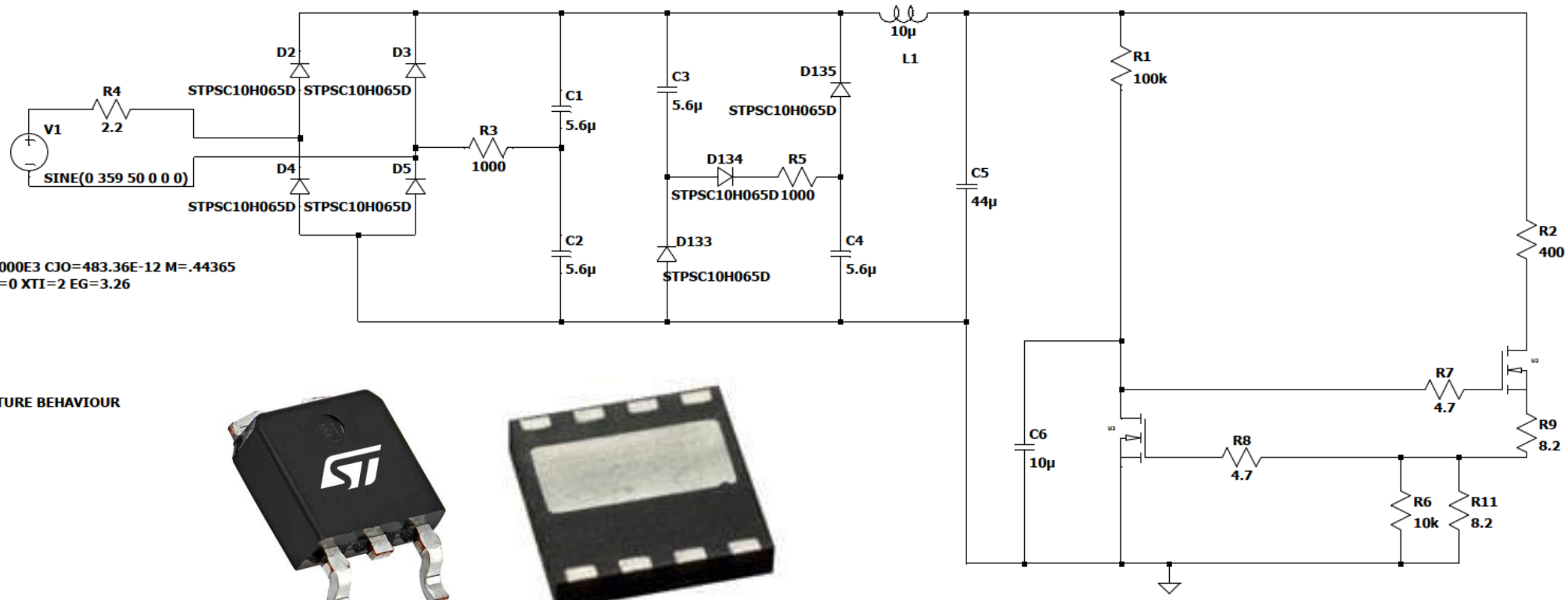
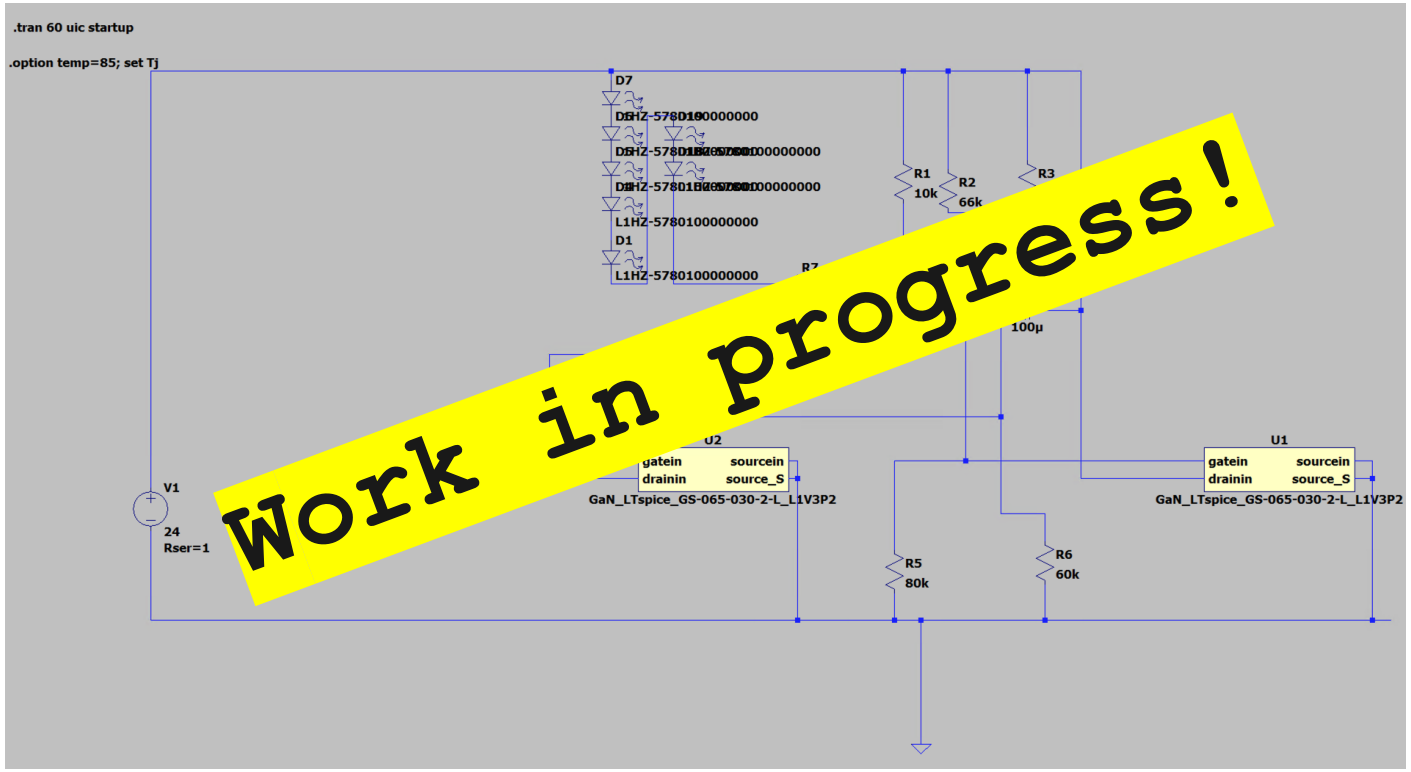
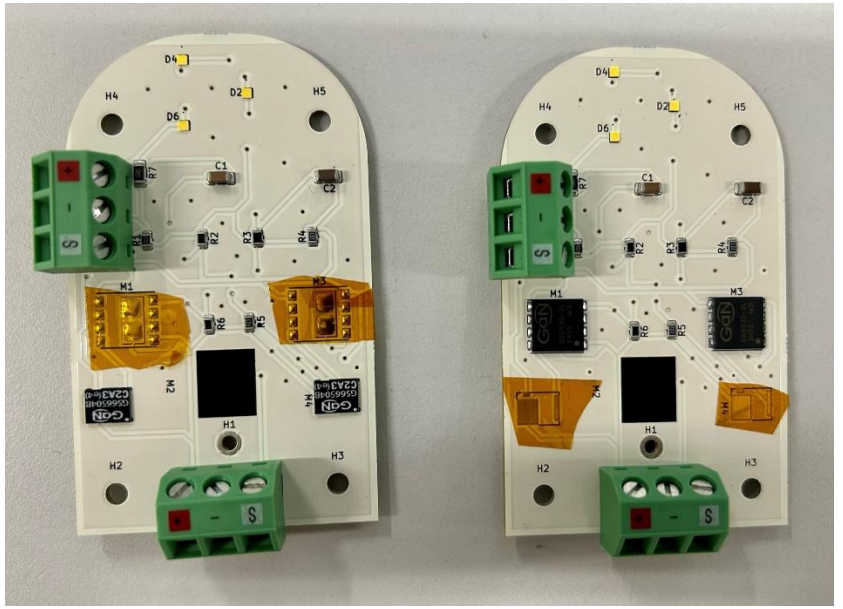


SiC and GaN active components + LEDs
Expected functionality up to 10kGy, mixed field.
(Limited by LEDs)

Radiation hard Flashing lighting





GaN active components + LEDs
Expected functionality up to 10kGy, mixed field.
(Limited by LEDs)

Approach

1. **Develop & build prototypes in house.**
2. **Qualify COTS based on fundamentals (GaN, SIC, LEDs).**
3. **Radiation tests at component (full dose) and system level (low dose).**
4. **Commercial manufacture, based on adaptation of existing products (new PCB, existing housings/molding/tooling).**
5. **Follow up to ensure BOM respected in manufacture.**
6. **Monitor in-situ performance and maintain BOM as components reach end of life.**

What is missing?

No batch/lot qualification

No enhanced QA/Documentation

No guarantees from the manufacturers vis-à-vis radiation performance

CERN takes the risk on radiation performance with our design.
All designs are published and free to use under CERN OHL.
Manufacturer provides CE documentation as a standard product.
Large order to start, then order as needed.

Summary

Emergency Lighting

COTS LED + Si

1kGy dose limit

Could be increased to 10kGy

Conventional Lighting

COTS LED + SiC + GaN

10kGy dose limit

(to 50% light output)

Flashing Lights

COTS LED + GaN

Work in progress

Back-up slides

Limits, constraints, costs

The LED is the weakest point – failure (50% expected) around 10kGy.

Also, lifetime dependent (50k-70k hours); hard to account for lifetime + radiation.

Power supply components (GaN/SiC) are much more durable.

Second generation lighting – replaceable LED modules?

Commercial radiation hard lights do exist!

Very expensive (up to 40x price increase!) but come with radiation QA & guarantees.

Our experience was a ~3-5x price increase on a “standard luminaire” at tender.

How to get to 10kGy with emergency lighting?

Replace Si diode bridge with SiC, but no internal client for this change (yet).

References

Open Hardware designs:

Emergency Lighting PSU - https://ohwr.org/project/radtol-led-psu/wikis/home

LED luminaire - https://ohwr.org/project/radtol-led-luminaire/wikis/home

Flashing beacon - https://ohwr.org/jdevine/rad-tol-led-beacon

Publications:

Radiation hardening of LED luminaires for accelerator tunnels (preprint) - https://arxiv.org/abs/1609.03481v1

Modelling of proton irradiated GaN-based high-power white light-emitting diodes - https://iopscience.iop.org/article/10.7567/JJAP.57.080304

Radiation Testing of Optical and Semiconductor Components for Radiation-Tolerant LED Luminaires - https://ieeexplore.ieee.org/document/9328680

High-energy proton irradiation effects on GaN hybrid-drain-embedded gate injection transistors - https://www.sciencedirect.com/science/article/pii/S002627141930863 7

Proton irradiation of GaN transistor based power supply operating in the linear region- https://ieeexplore.ieee.org/document/9857693

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