# LHC Roadmap - DR&D

## “We believe we can come ….. an end”

Niels vB, Martin vB - Jan 2026

https://indico.nikhef.nl/event/4027/

# DR&D Roadmap budget

## Agreed end of 2022

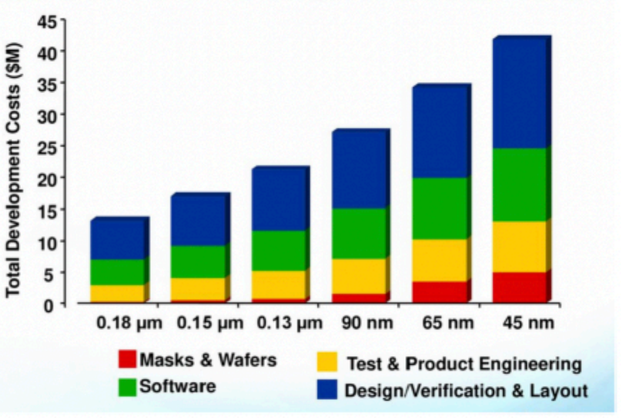
**For DR&D based on next two slides MvB**

| | Atlas | PDP | ALICE | DR&D | LHCb | |
|---|---|---|---|---|---|---|
| **Experiment** | 1.3 M€ | | 5.7 M€ | 0.5 M€<br>(1.5 M€ experiments)<br>(Infrastructure) | 7 M€ | |
| **R&D** | 1 M€ | | 2 M€ | 1.5 M | 1 M€ | |
| **FTE** | 1 M€ | 0.6 M€ | | | | |
| **Computing** | | 1.4 M€ | 0.5 M€ | | 1 M€ | |
| **Total** | 3.3 M€ | 2.0 M€ | 8.2 M€ | 2 M€ (1.5 M€) | 9 M€ | 24.5 M€<br>(26 M€) |

# First order cost estimate for sensor / ASIC

- R&D money for demonstrators via multi-project runs (MPW)
  - 15-20 k€ per $mm^2$, typically 4-6 $mm^2$, several runs
  - -> 200 – 300 k€ per ASIC/MAPS technology
  - Sensors (not shared) 50 – 100 k€ per run
  - Hybridization (bump bonding), readout etc.

Order 1 M€ for 2-3 different prototypes




- Note, much higher costs full for size ASIC: 65 nm 700 – 800 k€, 28 nm ~1.5 M€
  - Needed for large scale prototypes (upscaling to experiment), min. 2 runs
  - Might be needed in R&D phase if process modifications (e.g. new MAPS ideas) are not MPW compatible
  - Simulation / verification extremely important, experts required (e.g. Kevin Heijhoff, TCAD)

# R&D infrastructure, for ‘everybody’

- Characterisation infrastructure is expensive, especially if fast / HF
- Share between R&D and experiments, technical groups

Wire bonding machine 250k (recently renewed)
Probe station(s)
    automated for ASIC probing 200-300k
    small manual one for sensor prototyping (cold, dark, irradiated samples) 50k
SEM 50-70k
C/V, I/V etc. 100k
Beam telescope 50 – 100k
RF probes, scope, VNA, amplifiers 500k – 1M
Additional lasers 50k each.
Heavy server for simulation + SW 50k?
Cooling systems 50k
SEU / radiation testing 50k
Fast generators
Equipment for interconnect?
sputter machine?
heavy X-ray?
near-IR camera?

Rough estimate 1.5 -2 M€
Part of roadmap?

# Roadmap budget

## In 2026 for DR&D

- For DR&D:
  - Infrastructure or test equipment:  0.5 M€
  - Prototyping 0.5 M€ - was 1.5 M€ in 2022
  - Maybe *remaining* funds at the end of the FASTTRACK roadmap, we had leftover budget form the previous roadmap that we've used for Fast Timing R&D

| | | | Partial Totals Material | Partial Totals Personnel | Total Material | Total Personnel |
|---|---|---|---|---|---|---|
| ALICE | Detector | Sensor | 3.800 | 7.216 | 8.100 | 7.929 |
| | | Mechanics | | | | |
| | | Module Assembly | | | | |
| | | Cooling | | | | |
| | | Readout | | | | |
| | | Power | | | | |
| | Common Funds | Common Funds | 1.500 | 0.000 | | |
| | R&D | Sensor Submission Costs | 2.300 | 0.187 | | |
| | | Characterisation | | | | |
| | | R&D | | | | |
| | Computing | Computing | 0.500 | 0.527 | | |
| ATLAS | Detector | Detector | 0.500 | 0.000 | 2.300 | 1.650 |
| | Common Funds | Common Funds | 0.000 | 0.000 | | |
| | R&D | Characterisation | 1.800 | 1.150 | | |
| | | Sensor/ASIC | | | | |
| | | Readout | | | | |
| | | Cooling | | | | |
| | Computing | Computing | 0.000 | 0.500 | | |
| PDP | Preproduction Materia for technical readiness | Purchase costs | 1.400 | 0.000 | 1.400 | 0.600 |
| | | System costs | | | | |
| | | Power costs | | | | |
| | | Cooling costs | | | | |
| | Personnel | Personnel | 0.000 | 0.600 | | |
| R&D | Blue Sky | Prototyping | 0.500 | 0.000 | 1.000 | 0.000 |
| | Characterisation | Common Infrastructure | 0.500 | 0.000 | | |
| | | Total Detector + Common Funds | | | | |
| | | Total R&D and computing | | | | |
| | | Total | 21.737 | 23.183 | 21.737 | 23.183 |
| | | In FASTTRACK Proposal | | | | |
| | | Material Grand-Total | | | | |
| | | Personnel Grand-Total | | | | |
| | | Personnel Grand-Total in FASTTRACK | | | | |

# Conclusion

- Based on current budget only 1.5 prototype sensors possible, plus some equipment for testing
- Manpower request, see 1.ALICE-LHCb_DRnD.xlsx
  - How was the R&D budget distributed in the *Internal Workbook*?
  - We request some manpower for sensor prototypes: PCB design and MT fabrication.
  - If needed, manpower could be requested for ASIC design and PCB test boards, but not before 2028, as ASIC designers are already fully committed to experiments until then.

# DR&D Info requested for Excel template

## See 1.ALICE-LHCb_DRnD.xlsx

From internal workbook

| | | | WP1 Sensors | | | | | | WP2 ASICs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | WP1.1 3D Hybrids Material | WP1.1 3D Hybrids Personnel | WP1.3 LGAD Hybrids Material | WP1.3 LGAD Hybrids Personnel | WP1.2 Monolithic Material | WP1.2 Monolithic Personnel | WP2.2 Monolithic Material | WP2.2 Monolithic Personnel | WP2.1 Hybrid ASICs Material | WP2.1 P |
| R&D | Blue Sky | Prototyping | 0.100 | | 0.100 | | 0.100 | | 0.100 | | 0.100 | |
| | Characterisation | non Infrastructure | 0.100 | | 0.100 | | 0.100 | | 0.100 | | 0.100 | |

| Description of Activity | Nikhef Project | Deliverable Type | FASTTRACK WP | Optional Material Cost (MEUR) | | Q2/2026-Q1/2027 | Q2/2027-Q1/2028 | Q2/2028-Q1/2029 | Q2/2029-Q1/2030 | Q2/2030-Q1/2031 | Q2/2031-Q1/2032 | Q2/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sensors | DR&D | | WP1.1 /WP1.2/ WP1.3 | 0.300 | | 0.1ETA\|0.1MTD | 0.1ETA\|0.1MTD | 0.1ETA\|0.1MTD | 0.1ETA\|0.1MTD | 0.1ETA\|0.1MTD | 0.1ETA\|0.1MTD | 0.1E |
| ASICs | DR&D | | WP2.1 /WP2.2 | 0.200 | | NO | NO | | | | | |