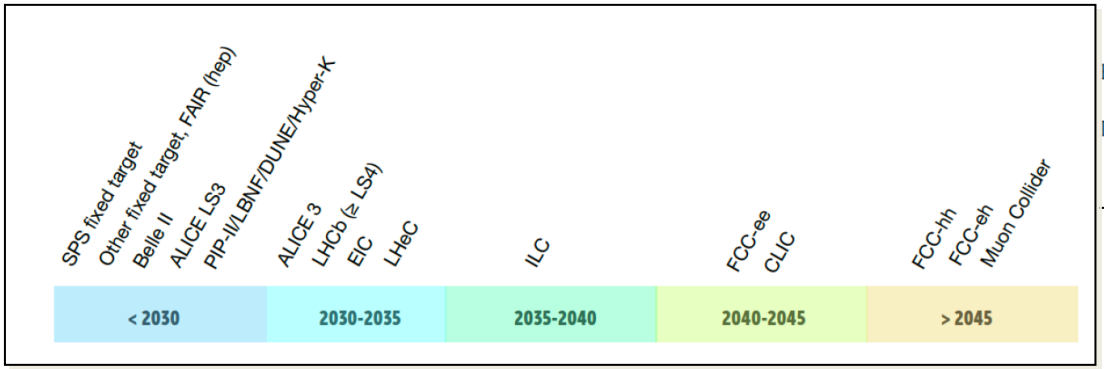
R&D CMOS for FCCee
& plans within the ECFA DRDs

Detector R&D Roadmap: themes (DRDTs)



References: ECFA/RC/21/510
CERN-ESU-017
DOI: 10.17181/CERN.XDPL.W2EX

< 2030 | 2030-2035 | 2035-2040 | 2040-2045 | > 2045

Solid state

- **DRDT 3.1** Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
- **DRDT 3.2** Develop solid state sensors with 4D-capabilities for tracking and calorimetry
- **DRDT 3.3** Extend capabilities of solid state sensors to operate at extreme fluences
- **DRDT 3.4** Develop full 3D-interconnection technologies for solid state devices in particle physics

DRDT 3.1 - Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors.

Developments of Monolithic Active Pixel Sensors (MAPS) should achieve very high spatial resolution and very low mass aiming to also perform in high fluence environments. To achieve low mass in vertex and tracking detectors, thin and large area sensors will be crucial. For tracking and calorimetry applications MAPS arrays of very large areas, but reduced granularity are required for which cost and power aspects are critical R&D drivers. Passive CMOS designs are to be explored, as a complement to standard sensors fabricated in dedicated clean room facilities, towards hybrid detector modules where the sensors is bonded to an independent ASIC circuit. Passive CMOS sensors are good candidates for calorimetry applications where position precision and lightness are not major constraints (see Chapter 6). State-of-the-art commercial CMOS imaging sensor (CIS) technology should be explored for suitability in tracking and vertex detectors.

European programs (AIDAInnova, Eurizon)

ECFA Detector Technology roadmap

GRAM Master Project

DEPHY

C4PI platform

Design, build and exploit CMOS pixels sensors with low material budget & high granularity
In order to contribute to the construction of a vertex & a tracking detectors

Future Higgs Factories

Heavy ions experiments, Belle-2, etc.

Approach the Higgs factories vertex detector requirements

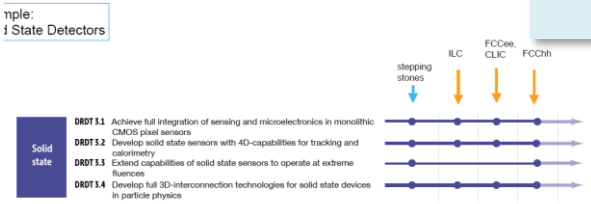
Input for detector simulations

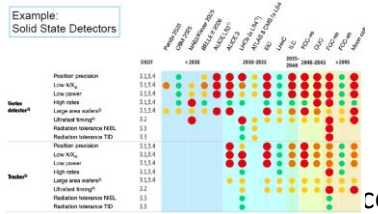
Exploit fully the potential of the CMOS technology

MIMOSIS chip family (180 nm)

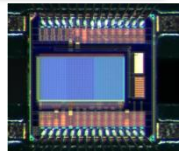
Optimize the parameters of the technology (e.g. sensitive layer)

Maintain & develop the know how to build sensors to be installed in real experiments





R&D 65 nm



Large surfaces (stitching)

Bent sensors

Exploring new architectures

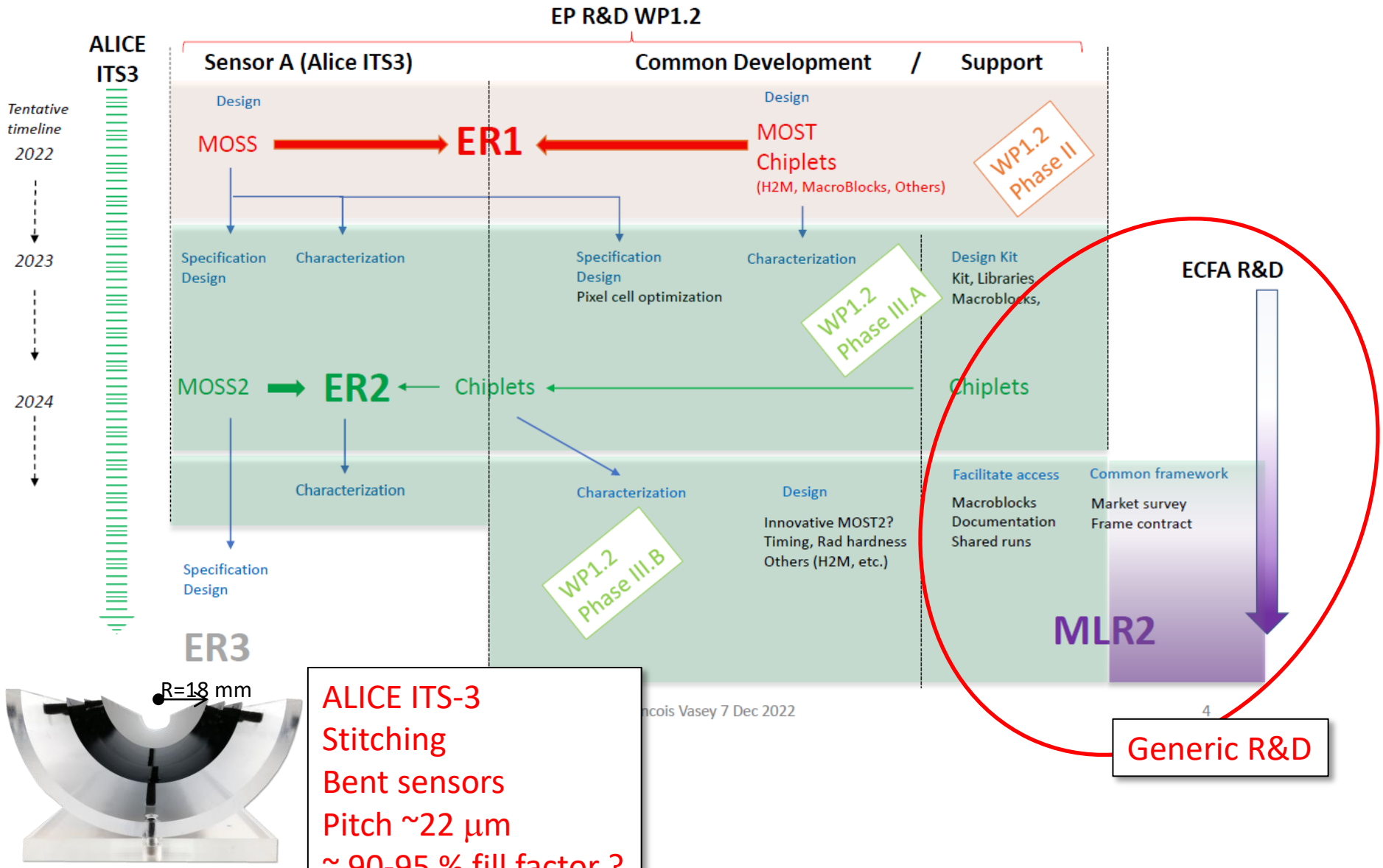
Integration

Emerging technologies
(e.g. double tier)

DRD organisation

- DRD3 (Solid State Detector)
  - ✓ CERN workshop : March 22-23rd 2023
- DRD7 (Electronics)
  - ✓ CERN workshop : March 14-15th 2023
- CMOS activities mainly in DRD3 but both will contribute
  - ✓ 1h30 session dedicated to CMOS in each DRD.
  - ✓ Discussions ongoing on the final organization
  - ✓ Both DRD will cover also other technologies
- CMOS technologies
  - ✓ Smaller feature sizes allow to improve performances
    - Spatial Resolution, time resolution, Power, etc.
  - ✓ Tower 180 nm: MIMOSIS, ALPIDE, OBELIX, MALTA, etc.
    - Technology possibly driven by C4Pi in the future
  - ✓ TPSco 65 nm: ALICE ITS-3 ⇨ Technology endorsed by CERN
  - ✓ Others (e.g. Lfoundry).
- R&D 65 nm: x 3 costs w.r.t. 180 nm
  - ✓ R&D strategy based on common submissions

Submission plans for Tower-65 nm calendar (F. Vasey CERN)

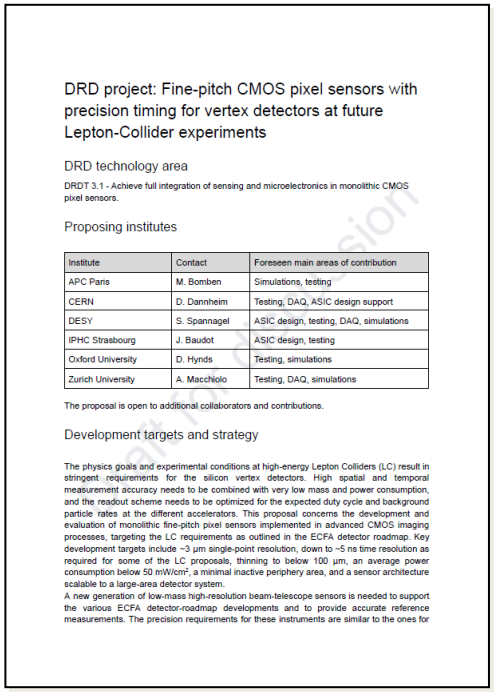


ALICE ITS-3
Stitching
Bent sensors
Pitch ~22 µm
~ 90-95 % fill factor ?

Generic R&D

Project proposal for lepton colliders to DRD3

- « Fine-pitch CMOS pixel sensors with precision timing for vertex detectors at future Lepton-Collider experiments »
- Framework: 65 nm technology
  - ✓ Targets 3 μm spatial resolution, improved time resolution (5-500 ns), controlled Power (< 50 mW/cm^2), data flow (10-100 MHz/cm^2) and low material budget (50 μm thickness)
- Proposing Institutes: CERN, DESY, IPHC, APC, etc.
  - ✓ Open to other participations
  - ✓ Includes all Higgs factory concepts
- Goal: gather groups to reach a critical size allowing the submission of demonstrators dedicated to Higgs factories
- Deliverables
  - ✓ Proof of concept demonstrator (MLR2)
  - ✓ Large size demonstrator
    - Allowing to equip new generation of beam telescopes



DRD project: Fine-pitch CMOS pixel sensors with precision timing for vertex detectors at future Lepton-Collider experiments

DRD technology area

DRDT 3.1 - Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors.

Proposing institutes

Institute	Contact	Foreseen main areas of contribution
APC Paris	M. Bomben	Simulations, testing
CERN	D. Dannheim	Testing, DAQ, ASIC design support
DESY	S. Spannagel	ASIC design, testing, DAQ, simulations
IPHC Strasbourg	J. Baudot	ASIC design, testing
Oxford University	D. Hynds	Testing, simulations
Zurich University	A. Macchiolo	Testing, DAQ, simulations

The proposal is open to additional collaborators and contributions.

Development targets and strategy

The physics goals and experimental conditions at high-energy Lepton Colliders (LC) result in stringent requirements for the silicon vertex detectors. High spatial and temporal measurement accuracy needs to be combined with very low mass and power consumption, and the readout scheme needs to be optimized for the expected duty cycle and background particle rates at the different accelerators. This proposal concerns the development and evaluation of monolithic fine-pitch pixel sensors implemented in advanced CMOS imaging processes, targeting the LC requirements as outlined in the ECFA detector roadmap. Key development targets include ~3 μm single-point resolution, down to ~5 ns time resolution as required for some of the LC proposals, thinning to below 100 μm, an average power consumption below 50 mW/cm^2, a minimal inactive periphery area, and a sensor architecture scalable to a large-area detector system.
A new generation of low-mass high-resolution beam-telescope sensors is needed to support the various ECFA detector-roadmap developments and to provide accurate reference measurements. The precision requirements for these instruments are similar to the ones for

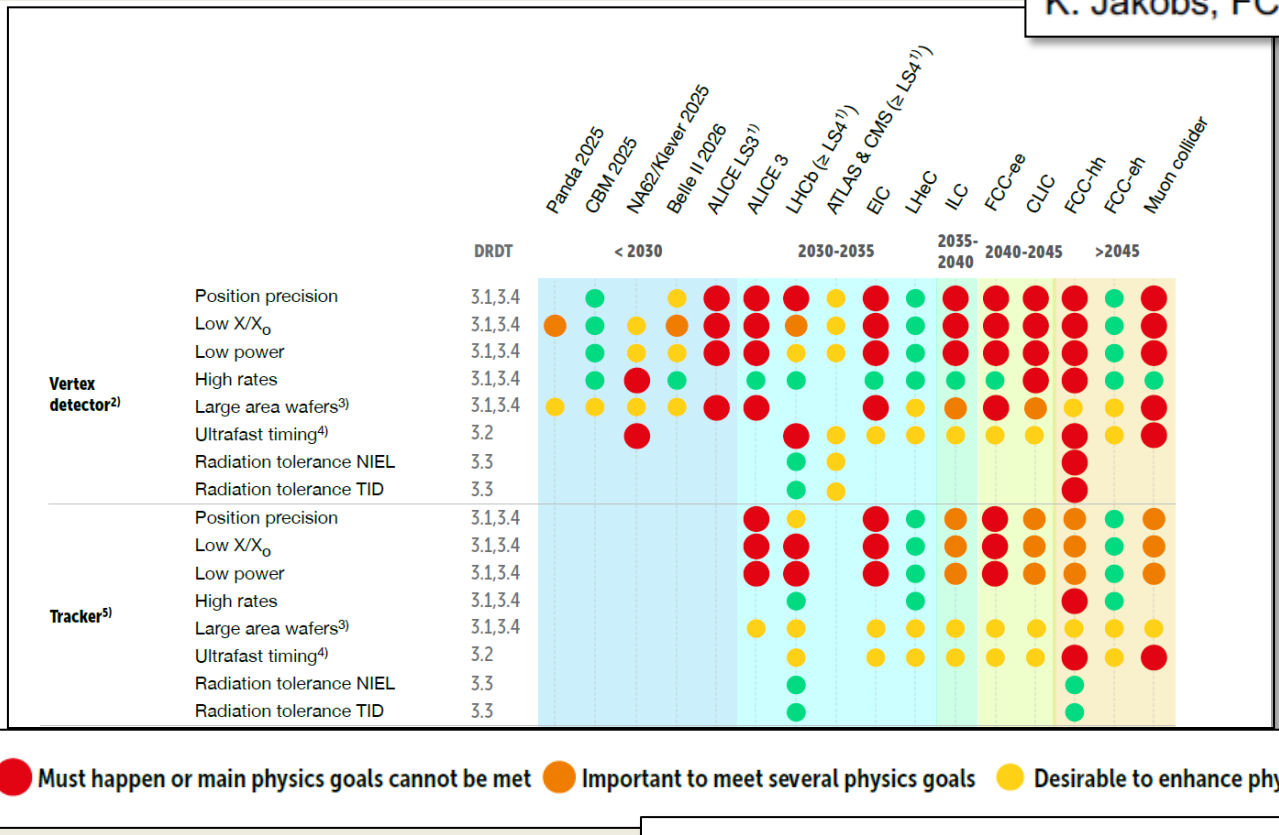
Back up

Synergies

ECFA recognizes the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies at future Higgs factories to gather. ***ECFA supports a series of workshops*** *with the aim to* ***share challenges and expertise, to explore synergies in their efforts*** *and to respond coherently to this priority in the European Strategy for Particle Physics (ESPP).*

Goal: bring the entire e^+e^- Higgs factory effort together, foster cooperation across various projects; collaborative research programmes are to emerge

K. Jakobs, FCC Physics Workshop, Feb 2022



+ integration know-how (e.g. ALICE, Belle-2, CBM, etc.)

CMOS Pixel Sensors @ IN2P3

- New IN2P3 internal organisation for CMOS R&D
  - ✓ 2 national master projects (provides R&D funding)
    - GRAM (Higgs factories, Belle-II, ALICE, heavy ions)
    - DEPHY (high rates & high doses)
  - ✓ 1 Platform C4PI @ IPHC
- IPHC reviewed completely in fall 2022 (twice)
  - ✓ CNRS commission ⇨ very positive outcome for CMOS activities @ IPHC
  - ✓ HCERES
- Scientific council of IN2P3 recently reviewed 2 projects carried by IPHC:
  - ✓ Belle-II upgrade (presented by J.B.)
  - ✓ ALICE ITS-3 upgrade Accepted by IN2P3 !
  - ⇨ Expects positive outcome
- Strasbourg prospectives for all CMOS activities @ IPHC
  - ✓ Involves C4PI and physics teams (PICSEL, Belle-2, ALICE, etc.)
    - Ongoing Q1-Q2 2023