## Séminaire projets APC 2023

# CMOS 65 nm R&D

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APC & UPC



## **ECFA Detector R&D Roadmap**



2020 European Particle Physics Strategy Update (EPPSU)



High-priority future initiatives: e+e- Higgs/Z/top factories





THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP

The European Committee for Future Accelerators Detector R&D Roadmap Process Group

https://cds.cern.ch/record/2784893/

Roadmap organised in "Detector R&D Themes" (DRDTs) and "Detector Community Themes" (DCTs)



Illustration of microelectronics circuitry integrated with a detecting medium as a single monolithic solid-state detector. (© ALICE collaboration)



Students and young scientists working on the construction of prototype detector modules. (© CERN)

Takeaway message: "detector readiness should not be the limiting factor in terms of when the facility in question can be realised"

### DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

			< 2030	2030-2035	2035- 2040	2040- 2045	> 2045
iaseous	DRDT 1.1	Improve time and spatial resolution for gaseous detectors with long-term stability	-	-	-	*	
	DRDT 1.2	Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out	-	•	•	-	
	DRDT 1.3	schemes Develop environmentally friendly gaseous detectors for very large areas with high-rate capability		•	-	-	
	DRDT 1.4	Achieve high sensitivity in both low and high-pressure TPCs		•			
Liquid	DRDT 2.1	Develop readout technology to increase spatial and energy resolution for liquid detectors					manding uired for
	DRDT 2.2	Advance noise reduction in liquid detectors to lower signal energy thresholds					d in the זה then act
	DRDT 2.3	Improve the material properties of target and detector components in liquid detectors		•			llustrated ;) towards
	DRDT 2.4	Realise liquid detector technologies scalable for integration in large systems		•			cifications.
	DRDT 3.1	Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors	-	•	•	•	-
Solid state	DRDT 3.2	Develop solid state sensors with 4D-capabilities for tracking and				-	
	DRDT 3.3	calorimetry 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	-	•	-	•	-

### https://indico.cern.ch/event/1214410/

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 participants

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	A. Besson	ASIC design, testing	
Oxford University	D. Hynds	Testing, simulations	
Zurich University	A. Macchiolo	Testing, DAQ, simulations	

**R&D** using **65 nm technology** to achieve high **single point resolution** (3 μm), high **temporal accuracy** (5ns), low **mass** (100 μm thick) & low **power** ( < 50 mW/cm<sup>2</sup>)

Access to TPSCo65 CMOS imaging process with 65 nm feature size via **CERN**/ALICE



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### Lightweight, granular and fast detector → Tempting eh? ☺



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Multi-year expertise in simulations (TCAD/MC) and testing (cleanroom/testbeams)



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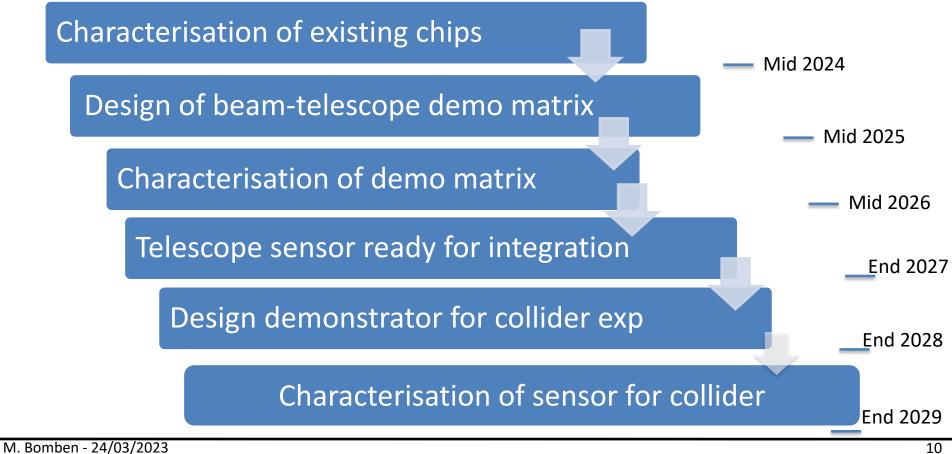
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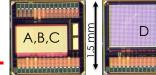
### Staged project – see next slide

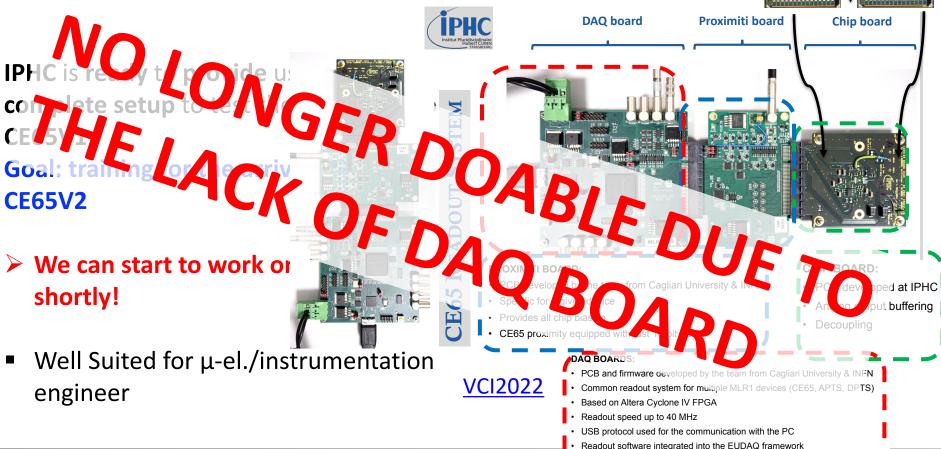


## Timeline



# Opportunity for contribution – now 😳





(compatibility with the beam test infrastructure)



# **QUESTIONS?**



## European Particle Physics Strategy Update (2020)

 Projects listed in the Deliberation Document of the European Particle Physics Strategy Update (EPPSU) [Ch0-2] as either "High-priority future initiatives" or "Other essential scientific activities for particle physics"; e.g.:

➢ HL-LHC

- Long baseline neutrino detectors
- e+e- Higgs/Z/top factories
- hh machine @ 100 TeV

The highest priority laid down by the updated ESPP is for a future Higgs factory to thoroughly explore the properties of this completely new type of particle, which is seen as a key to a much deeper understanding of how the Universe works. < 2030 2030- 2035- 2040-2035 2040 2045 > 2045

PID and Photon Develop Photosensors for extreme environments   DB07 42 Develop Photosensors for extreme environments   DB07 43 Develop Photosensors for extreme environments   DB07 44 Develop Photosensors for extreme environments   DB07 45 Promote the development of advanced quantum sensing technologies   DB07 51 Promote the development of advanced quantum sensing technologies   DB07 52 trivestigate and adgat state-ot-the-art developments in quantum technologies to particle physics   DB07 53 Develop photosensors for extreme environments to allow exploration of emerging technologies and infrastructure   DB07 51 Develop paid provide advanced enabling capabilities and infrastructure energy and timing resolution   DB07 51 Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods   DB07 52 Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods   DB07 51 Develop notalistion - hard calorimeters with multi-dimensional readout for optimised use of particle flow methods   DB07 53 Develop notalistion of extreme radiation, rate and pile-up environments   DB07 74 Develop novel technologies for increased intelligence on the detector   DB07 75 Evaluate and adapt to emereging electronics and data processing technologies	DID and	DRDT 4.1	Enhance the timing resolution and spectral range of photon detectors	
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including environmental, radiation and beam aspects		DRDT 8.4	Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects	
DCT1   Establish and maintain a European coordinated programme for training in instrumentation	Training	DCT1		
DCT 2 Develop a master's degree programme in instrumentation		DCT 2	Develop a master's degree programme in instrumentation	

**Detector R&D Themes (DRDTs) and Detector Community Themes (DCTs).** Here, except in the DCT case, the final dot position represents the target date for completion of the R&D required by the latest known future acility/experiment for which an R&D programme would still be needed n that area. The time from that dot to the end of the arrow represents he further time to be anticipated for experiment-specific prototyping, procurement, construction, installation and commissioning. Earlier dots represent the time-frame of intermediate "stepping stone"

projects where dates for the corresponding facilities/experiments are nown. (Note that R&D for Liquid Detectors will be needed far into the uture, however the DRDT lines for these end in the period 2030-35 because developments in that field are rapid and it is not possible oday to reasonably estimate the dates for projects requiring onger-term R&D. Similarly, dotted lines for the DCT case indicate that beyond the initial programmes, the activities will need to be sustained joing forward in support of the instrumentation R&D activities).

### Exploring a new technology: TPSCo 65 nm



#### IPHC motivation to join CERN-lead effort

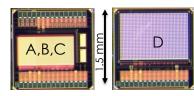
- Smaller feature size = smaller pixel
- Lower voltage hence power
- Stitching over 12" wafer
- Smaller feature size = more embedded functionalities

#### => SEE NEXT TALK BY WALTER SNOEYS <=

- Key requirements (future e+e- coll. / heavy-ion exp)
  - Position resolution  $\sigma_{sp} \lesssim 3 \ \mu m$
  - Low material budget 0.05 to 0.15 %  $X_0$  (power <<100 mW/cm<sup>2</sup>)
  - Large detection surface (> 100 cm<sup>2</sup>)
- Generic interest for MAPS performance
  - Large hit rate (>> 100 MHz/cm<sup>2</sup> e.g. for Belle II)
  - Time resolution from ns to ~10 ps (4D tracking, PID)

### IPHC contribution for charge collection studies

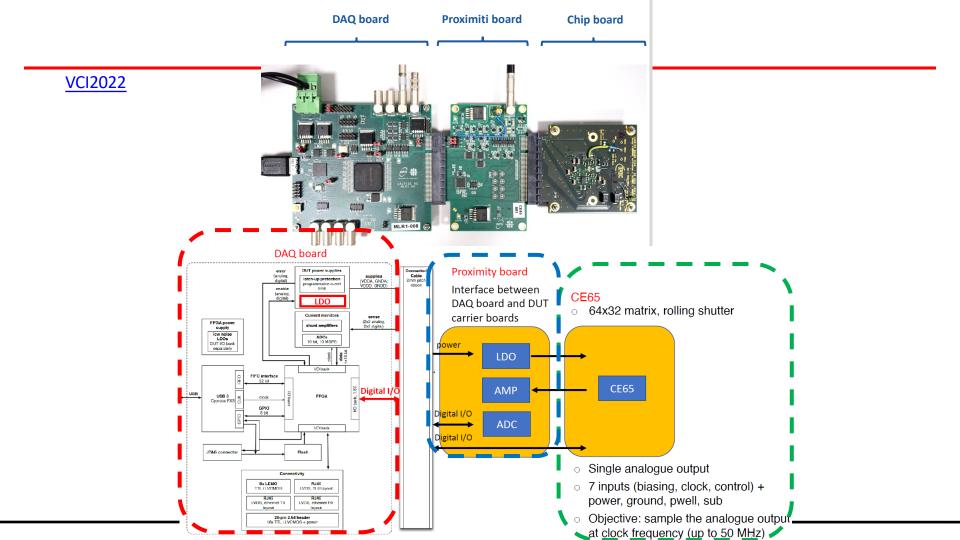
- CE-65 square pixel matrices
- Analogue output w rolling-shutter readout 10-40 MHz



https://indi.to/zL5xc S.Bugiel VCI 2022

Variant	pitch	Matrix size	Front-ends	Collection diode structure	Split
А				Basic	ing
В	15 µm	64x32	DC-SF DC-Amp AC-Amp	N-implant w gaps	various doping profiles
С				N-implant	
D	25 µm	48x32		basic	var

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## 65 vs 180 nm in a nutshell

65nm

pro: digital density of course

pro: 300mm wafers vs 200mm in 180

con: much less choice in substrate (essential only thin EPI 10-15um)

con: much more limited access to foundry than in 150/180 and typically no MPW for

prototyping

con: cost in engineering run ~ factor 2.7 over 150/180nm difficult in development cycle

### 180nm

pro: much wider range of substrate possible

pro: easier access to foundries and multiple foundries established in HEP and cheaper/ possibility of MPW for prototyping

con: logic density much smaller

con: costs at very large detectors (e.g. 50m2 + ) higher in 180 because 150/180 runs on 200mm wafers versus 65 on 300mm wafers