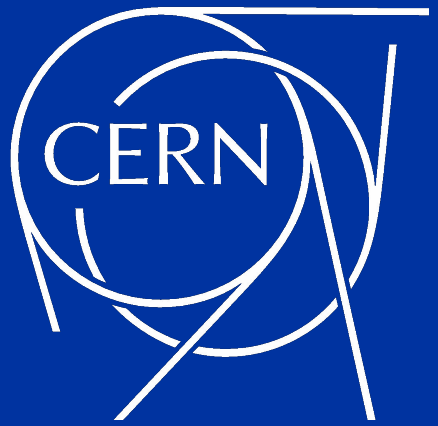


EP R&D Days
WP1.1 Silicon Hybrid Detector

Victor Coco, Paula Collins, Vagelis Gkougkousis(WP1.1 FELL), Jakob Haimberger, Marius Halvorsen (WP 1.1 DOCT), Eloi Pazos Rial (WP1.1 TECH), Heinrich Schindler, Viros Sriskaran (WP1.1 FELL), Raphael Dumps, Wiktor Bycznski….

… and a big thanks to collaborating institutes PSI, Nikhef, CNM, IGFAE-USC, CPPM, University of Oxford, …

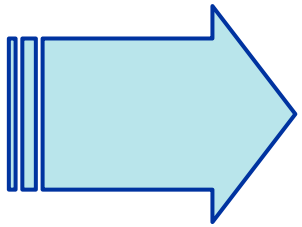
Motivations

MIP detection in next generation of collider experiments

from the CERN Strategic R&D Programme on Technologies for Future Experiments [CERN-OPEN-2018-006]

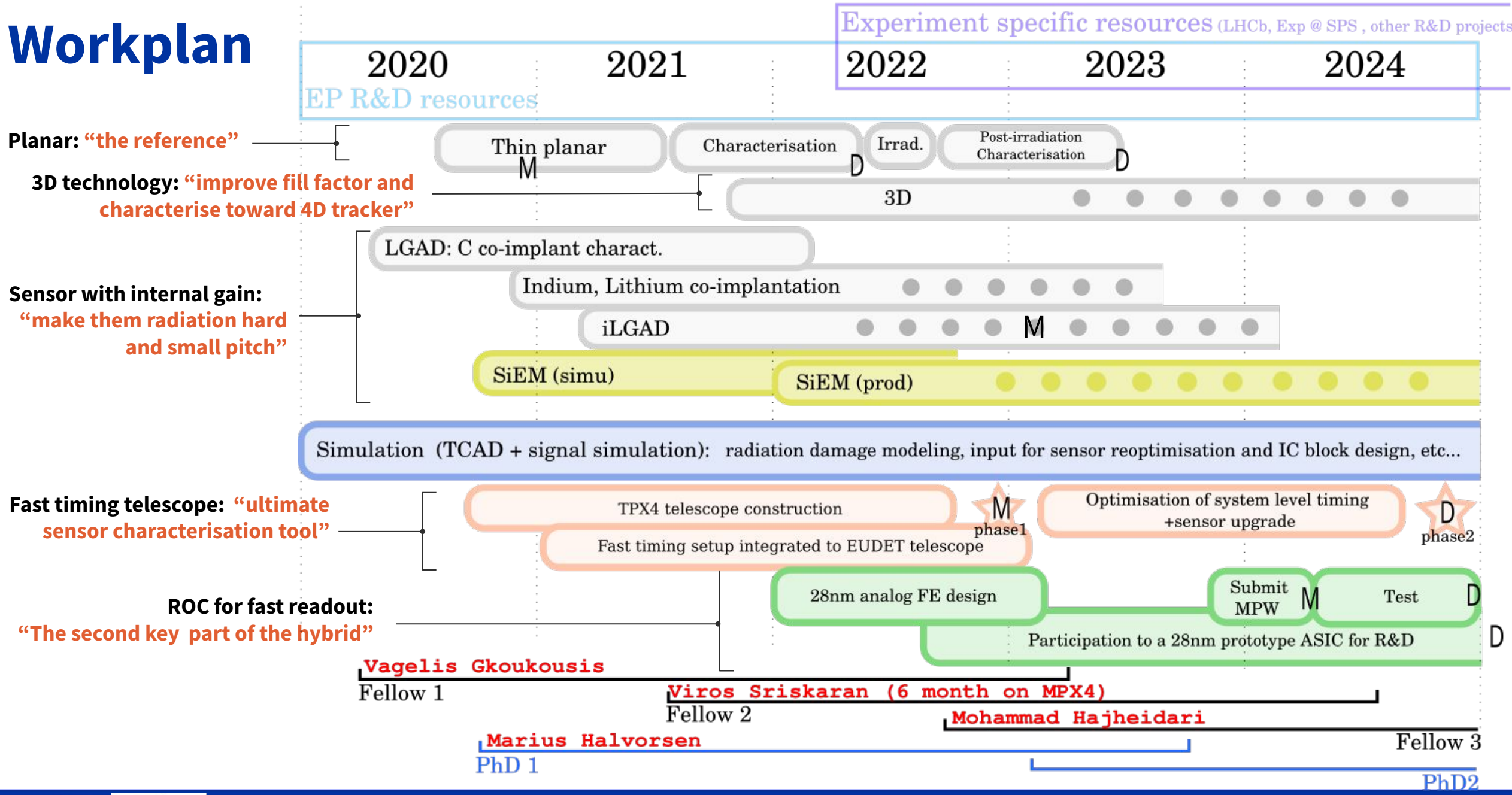
[fineprint in CERN-OPEN-2018-006]	HL-LHC	SPS	FCC-ee	FCC-hh
Total fluence [$n_{eq}cm^{-2}\ s^{-1}$]	$5x10^{16}$	10^{17}	10^{10}	10^{17}
Max Hit rate [$cm^{-2}\ s^{-1}$]	2-4G	8G	20M	20G
Material budget per layer [X_0]	0.1-2%	2%	0.3%	1%
Pixel size [μm^2] inner trackers	50x50	50x50	25x25	25x25
Temporal hit resolution [ps] inner trackers	~50	~40	-	~10

- **Time resolution 10 - 50 ps**
- **Pixel pitches down to 25µm**
- **Fluences up to $10^{17}n_{eq}/cm^2/y$**
- **Max hit rate up $20G/cm^2/s$**



Challenges for sensor
Challenges for front-end electronics

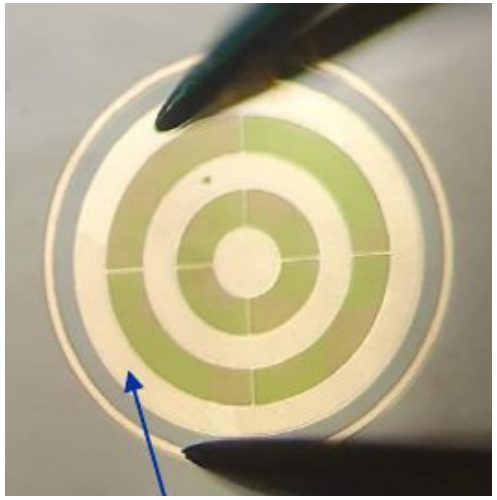
Workplan


Experiment specific resources (LHCb, Exp @ SPS , other R&D projects)
2020
2021
2022
2023
2024
EP R&D resources
Planar: "the reference"
Thin planar
M
Characterisation
D
Irrad.
Post-irradiation Characterisation
D
3D technology: "improve fill factor and characterise toward 4D tracker"
3D
Sensor with internal gain: "make them radiation hard and small pitch"
LGAD: C co-implant charact.
Indium, Lithium co-implantation
iLGAD
M
SiEM (simu)
SiEM (prod)
Simulation (TCAD + signal simulation): radiation damage modeling, input for sensor reoptimisation and IC block design, etc...
Fast timing telescope: "ultimate sensor characterisation tool"
TPX4 telescope construction
M
phase1
Fast timing setup integrated to EUDET telescope
Optimisation of system level timing +sensor upgrade
D
phase2
ROC for fast readout: "The second key part of the hybrid"
28nm analog FE design
Submit MPW
M
Test
D
Participation to a 28nm prototype ASIC for R&D
D
Vagelis Gkoukousis
Fellow 1
Viros Sriskaran (6 month on MPX4)
Fellow 2
Mohammad Hajheidari
Marius Halvorsen
PhD 1
Fellow 3
PhD2

Sensor
without gain

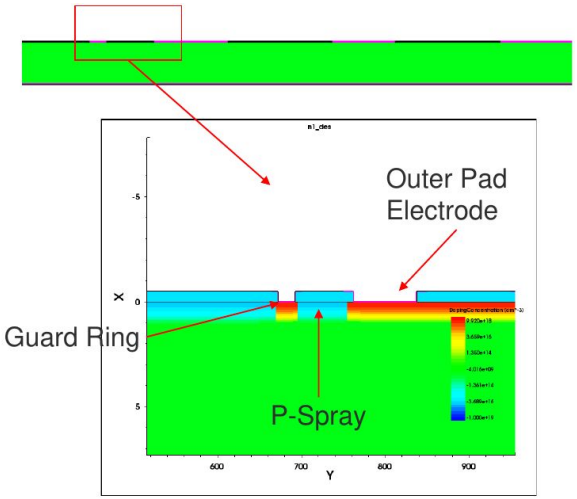
- **Planar sensors - the basics:**
  - Systematic study of the limit of this technology in terms of timing and radiation hardness up to $10^{17} n_{eq}/cm^2/y$, as function of thickness.
  - Benchmark for other sensors and "simple" lab to test models in simulations
  - Production of 50,100,200,300um sensors and structures finished in 2021
    - TPX4 sensors used for TPX4 telescope
    - Structures for systematic studies
  - Measurements on-going

    ⇒ **see Jakob's presentation**



A diode being IV'ed IRLat the SSD lab…

… the same being IV'ed with TCAD in simulation



- **3D sensors:**
  - Characteriation of existing technologies for timing performances (bef. and aft. irradiation)

    ⇒ **see Vagelis' presentation**

  - Working on a 3D thin column production targeting small pitches (<50um)
    - Discussion with producers to understand limitations
    - Hope to start before end of the year

Sensor
with gain

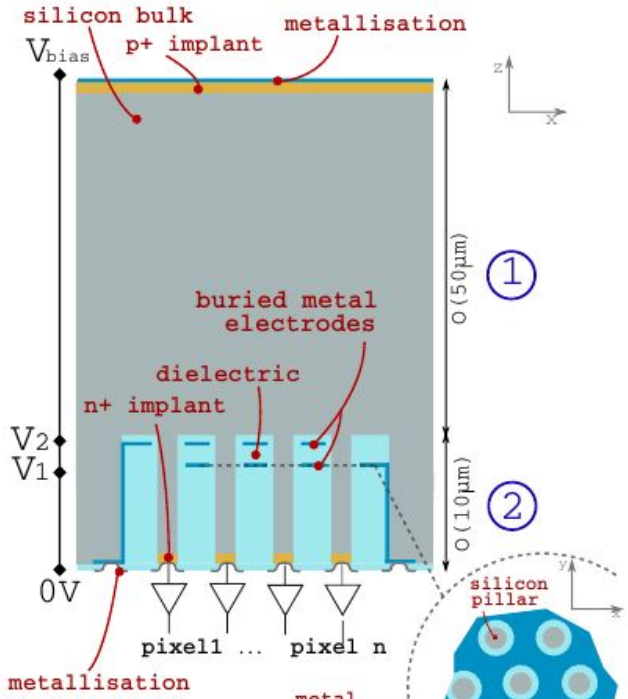
- **Silicon Electron Multiplier (SiEM)**
  - charge amplification without doping ⇒ fast timing, small pitch and possibly radiation hard
  - Concept to be demonstrated
  - Two production methods identified ⇒ **see Marius's presentation**
    - Collaboration with PSI for MaEtch, Marius @ PSI since Feb2022.
    - AIDAinnova Blue-Sky R&D funding with CNM for DRIE

- **Study of C co-implantation in LGAD**
  - Characterisation of an existing production (gain, efficiency, time resolution, doping profils, etc…)

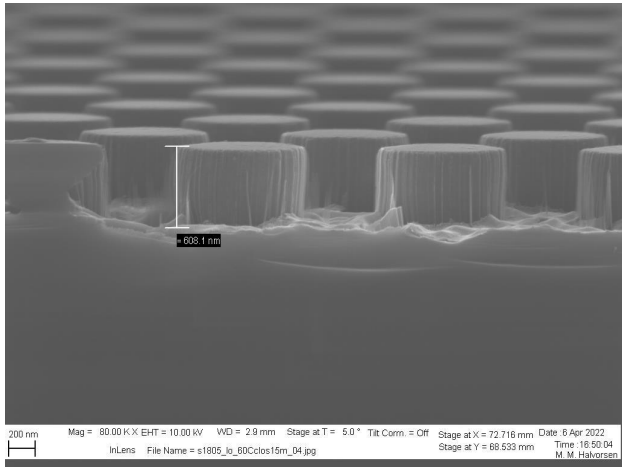
    ⇒ **follow up with indium and Lithium co-implentation submission [RD50 project]**

- **iLGAD production [RD50 project]**
  - charge amplification with small segmentation

} Delays @ producer



SiEM concept



Early trial of MacEtch technology

Readout ASIC

- **TPX4 gives the best out of the 65nm tech in terms of timing with small pitch pixels**
  - is / will be used a lot in the coming years (many sensor prod for R&D has 55umx55um pixels pitches structures).

- **For time resolution below 80ps, studies done with discrete electronics**
  - mis-representation of the final hybrid sensor capabilities
  - limited amount of channels ⇒ limited statistics in measurements campaigns

- **Generic 28nm block development in WP 5**

- **Developement of analog FE for fast timing (σ_t<50ps) and small pitch O(50um) and fast TDC in 28nm was one of the target of the WP1.1**

- **Coupled with a full ASIC design: PicoPix**
  - FE alone not enough to demonstrate overall timing performances
  - Need in the community for an ASIC to test fast timing / small pitch structures
  - Project of a demonstrator chip targeting LHCb U2 specifications - Collaboration EP-ESE, EP RD WP1.1, Nikhef, EP-LBD

⇒ **see Viros' presentation**

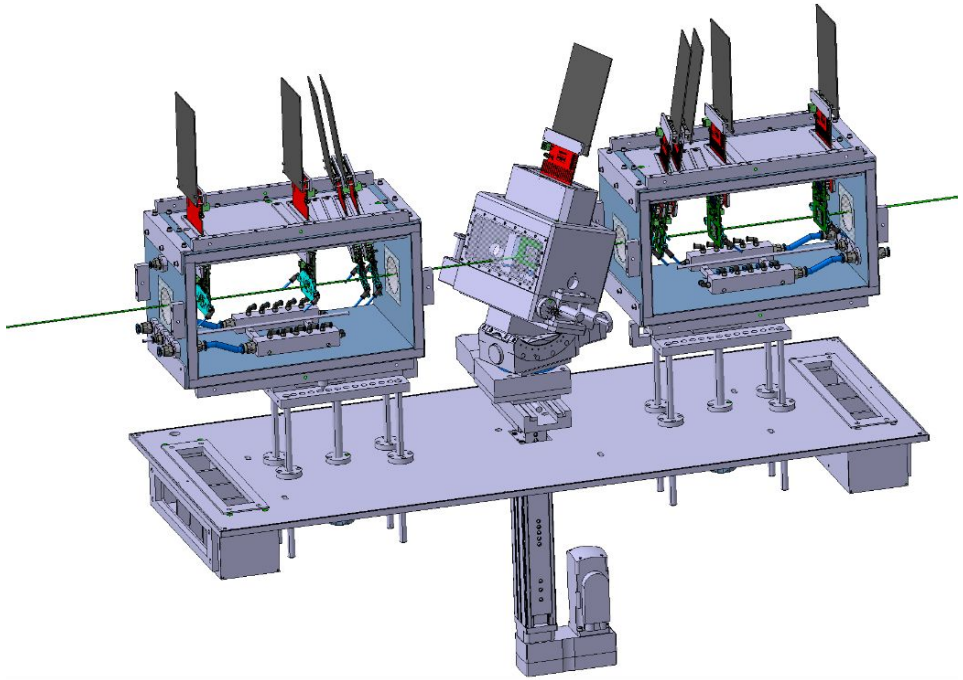
Characterisation

- **Many thanks to the SSD group for the support for IV/CV measurements**
- **β-source setup for efficiency and fast timing measurements**
- **Fast timing telescope:**
  - TPX4 telescope development (fast timing at high rate)
    - single arm version in 2021, results shown in Lecce workshop this week
    - two arm version in July, including latest TPX4 version
    - collab. with Nikhef, Oxford, Santiago, Dortmund, Manchester
  - LGAD based time stamping installed in EUDET telescope

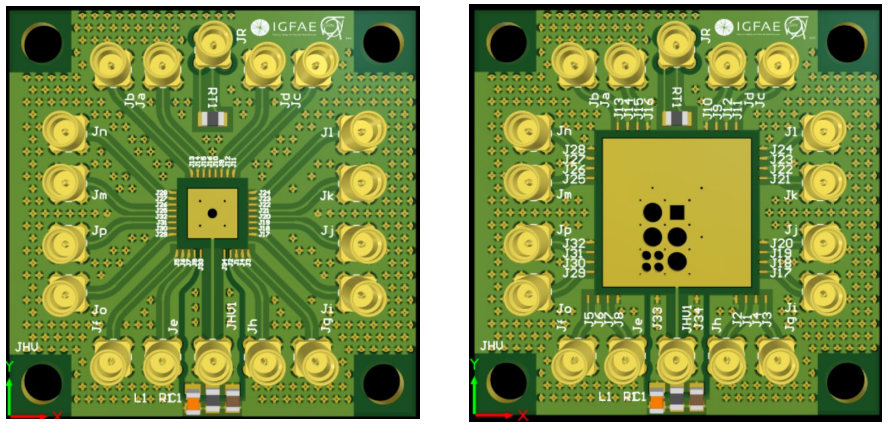
    ⇒ measurement campaign end of 2021 and right now!

- **Should think about how to persitify those development:**
  - 16ch board for fast sensor readout (developed with Santiago)
  - Structure holder for the IRRAD cold box
  - Improved β-source setup
  - EUDET telescope fast timing extension

    ⇒ see Vagelis' presentation



Design of the 2-arm TPX4 telescope (courtesy R. Dumps)



New sensor mezzanine for the 16ch board for big and small structures and better mechnical structure (courtesy E. C. Lemos, IGFAE)

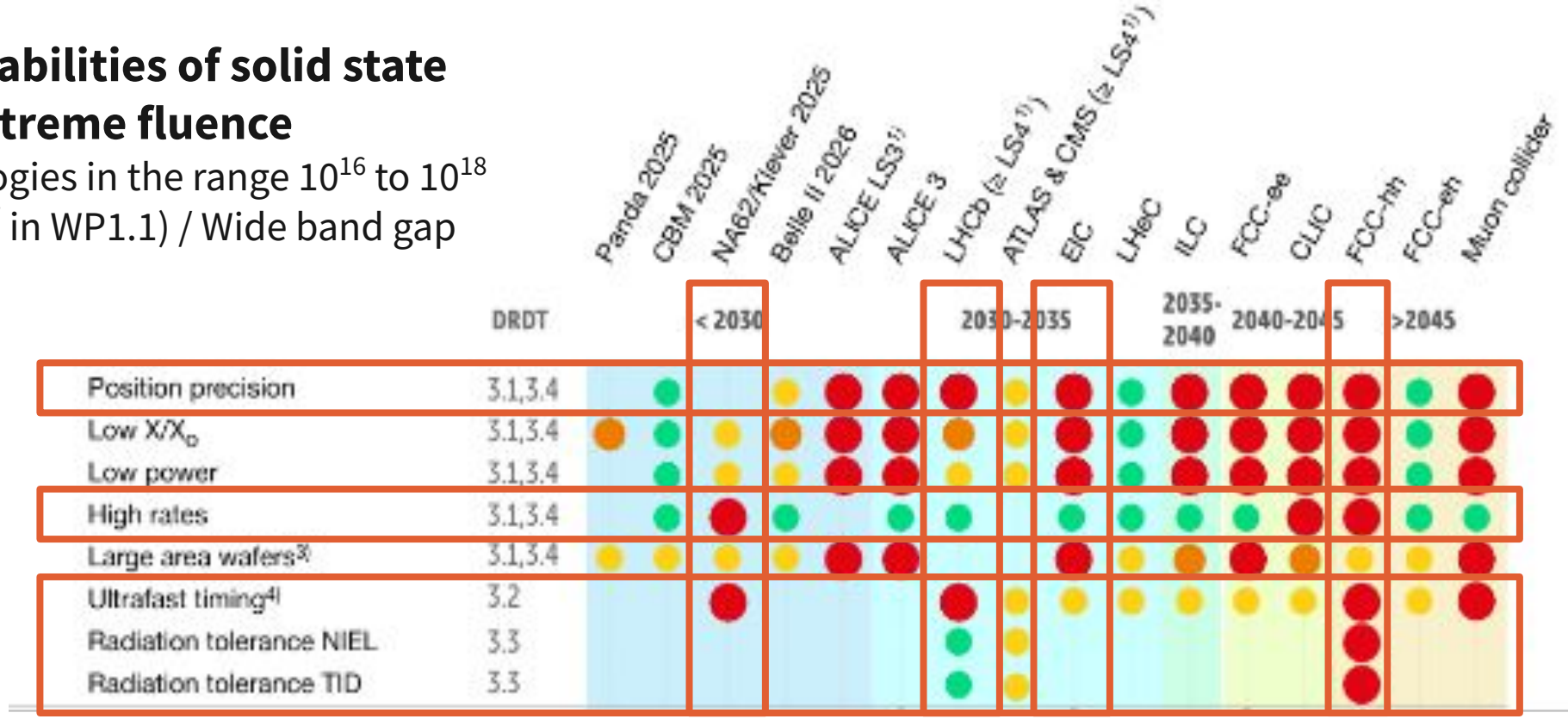
Link with ECFA Roadmap recommendations
Chapter 3 - DRDT-3.2 and DRDT-3.3

- **DRDT3.2: Developement of solid state sensors with 4D-capabilities for tracking and calorimetry**
  - characterisation of existing tech / development on new ones / increase rad. hard of timing sensor

- **DRDT 3.3: Extended capabilities of solid state sensors to operate at extreme fluence**
  - Limits of existing technologies in the range 10^{16} to 10^{18} $n_{eq}/cm^2/y$ (cover until 10^{17} in WP1.1) / Wide band gap materials (later…)

- **Some ECFA recom. covered in WP1.2, 1.3 and 1.4**

- **“Short” term target:**
  - LHCb / NA62 upgrades
  - Intensity frontier @ SPS
  - EIC?



from the 2021 ECFA Detector R&D roadmap [CERN-ESU-017]