



# ***AIDAINNOVA @ INFN***

## ***Advancement and Innovation for Detectors at Accelerators***

*progetto sottomesso 14 Maggio 2020*

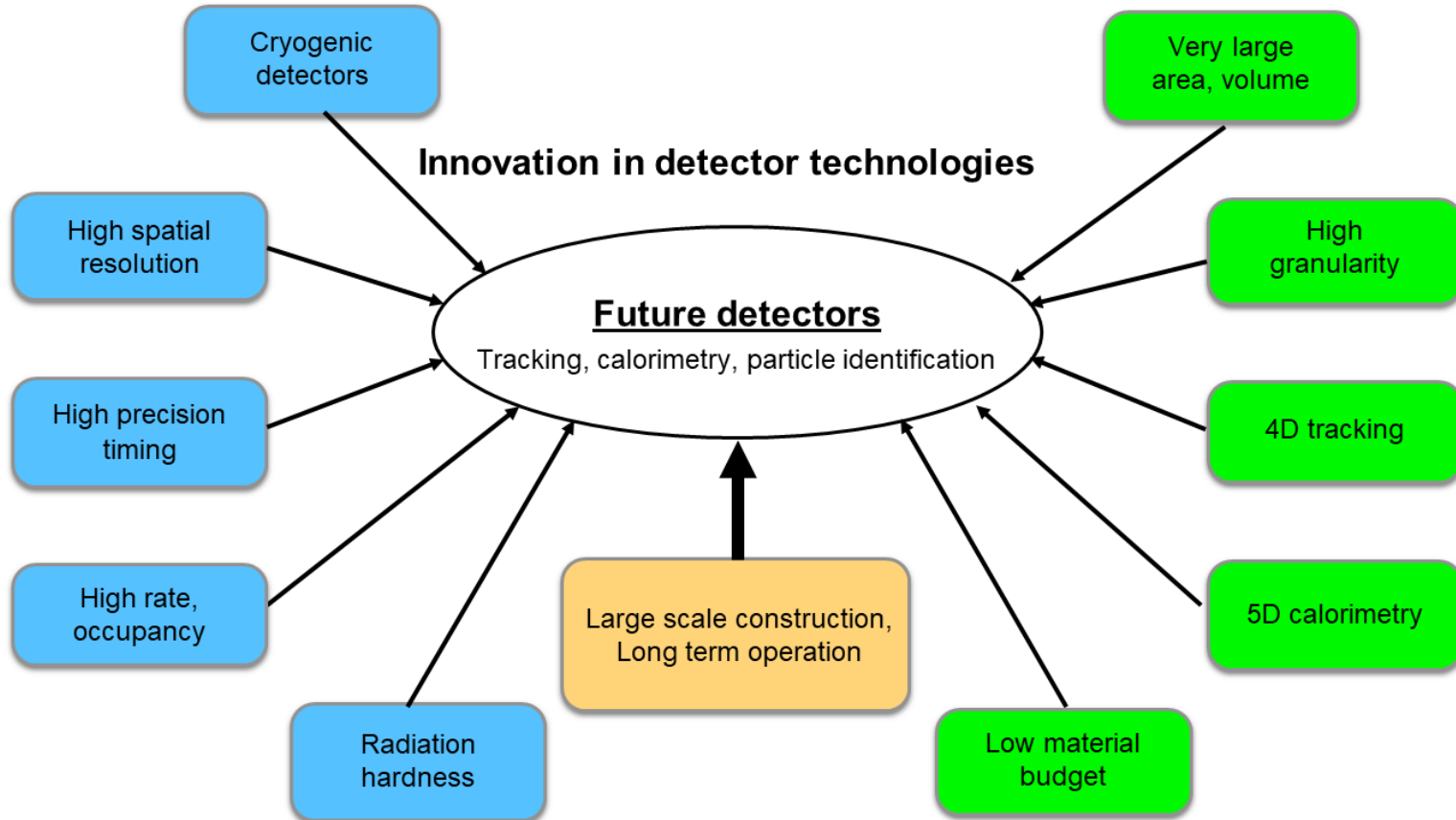
*INFN Scientific Coordinator: Nadia Pastrone – INFN-TO*

*INFN Financial Officer: Rosaria Porcu – INFN-TO*

***12 giugno 2020***

# AIDAInnova consortium: obiettivi

1. To push detector technologies beyond the state-of-the art, with a special emphasis to the needs of a **future Higgs factory**, and to offer well equipped infrastructures for testing detector systems to the European particle physics community;
2. To strengthen links between academic Institutes and European industry across the projects/experiments;
3. To contribute to maintaining the recognized worldwide leadership of particle physics in Europe;
4. To serve as the **European forum for the development of detectors and infrastructure for HEP**;
5. To support the co-development with Research Infrastructures and the European industry (especially SMEs) for large scale-scale production of detector instrumentation and for development of innovative products;
6. To enhance the **S&T training and job prospects for young European researchers**.



Istituto Nazionale di Fisica Nucleare

CAEN S.p.A.

Eltos S.p.A.

Fondazione Bruno Kessler

ASSOCIATED PARTNERS:

ENEA

GLASStoPOWER (spinoff-UniMIB)

Legend:

- Academia
- Industry
- ▲ RTOs

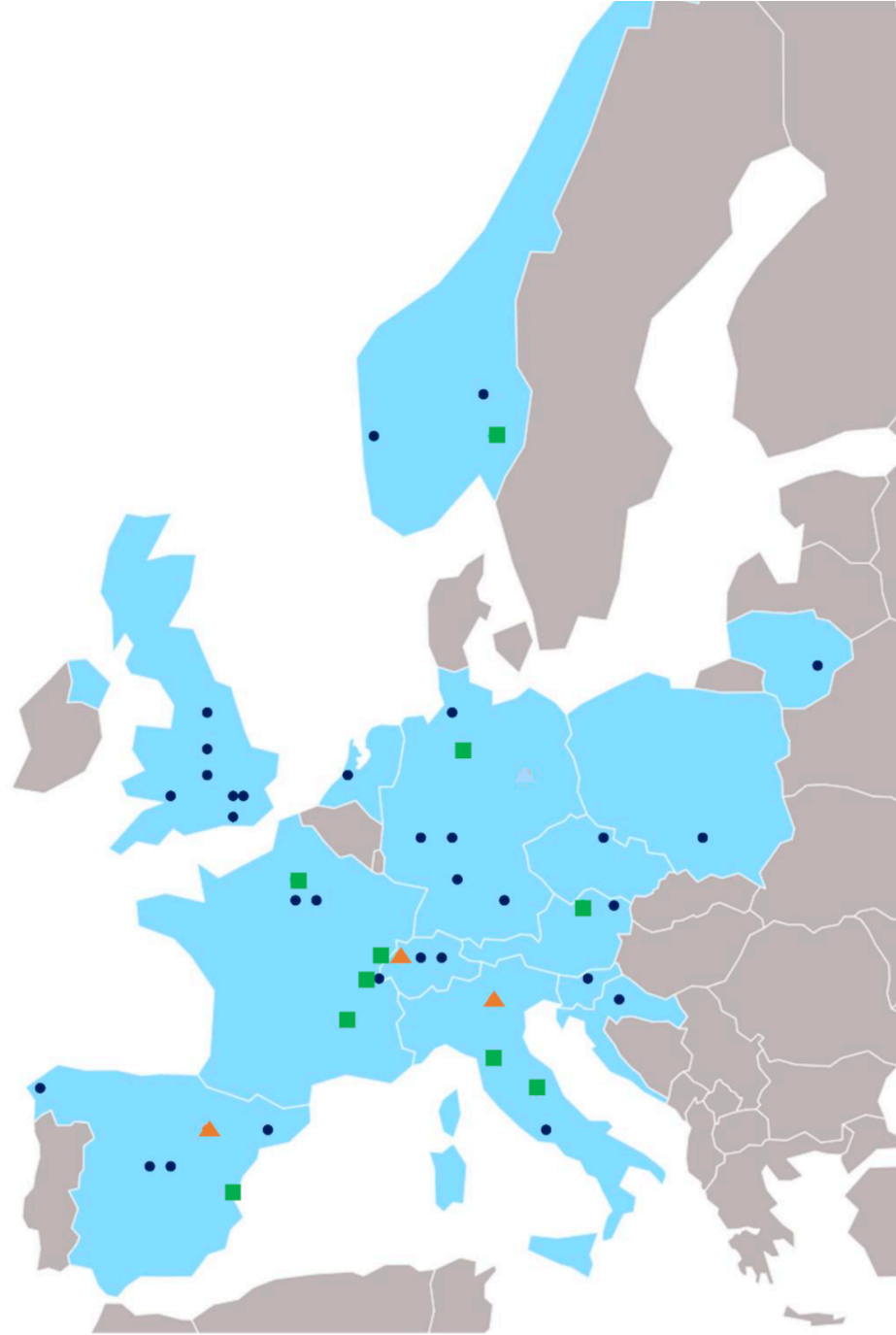
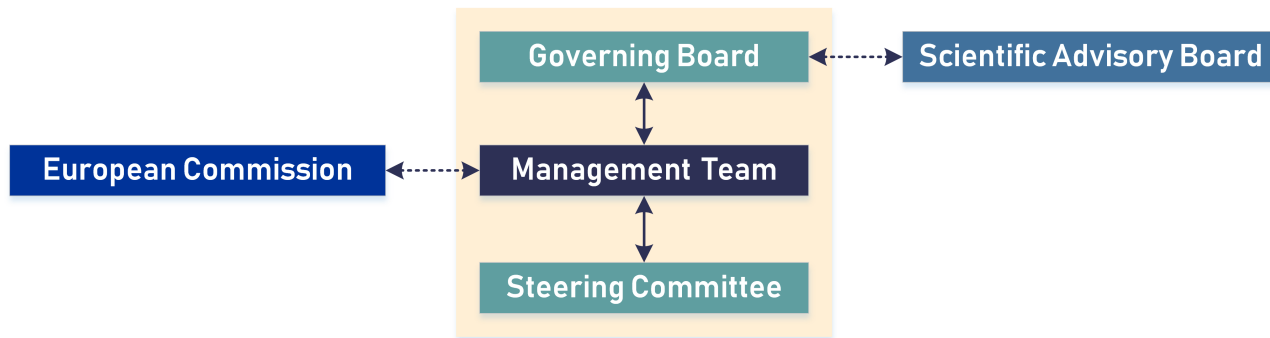


Figure 1: Map of beneficiaries and countries involved in AIDAinnova.

# Management

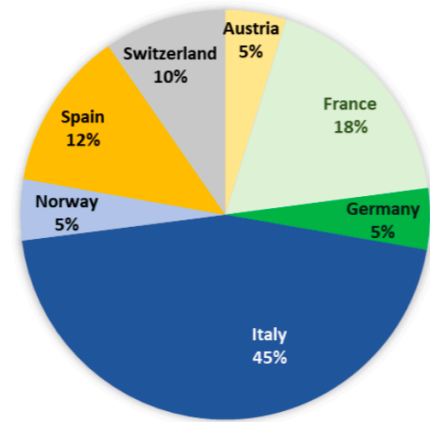
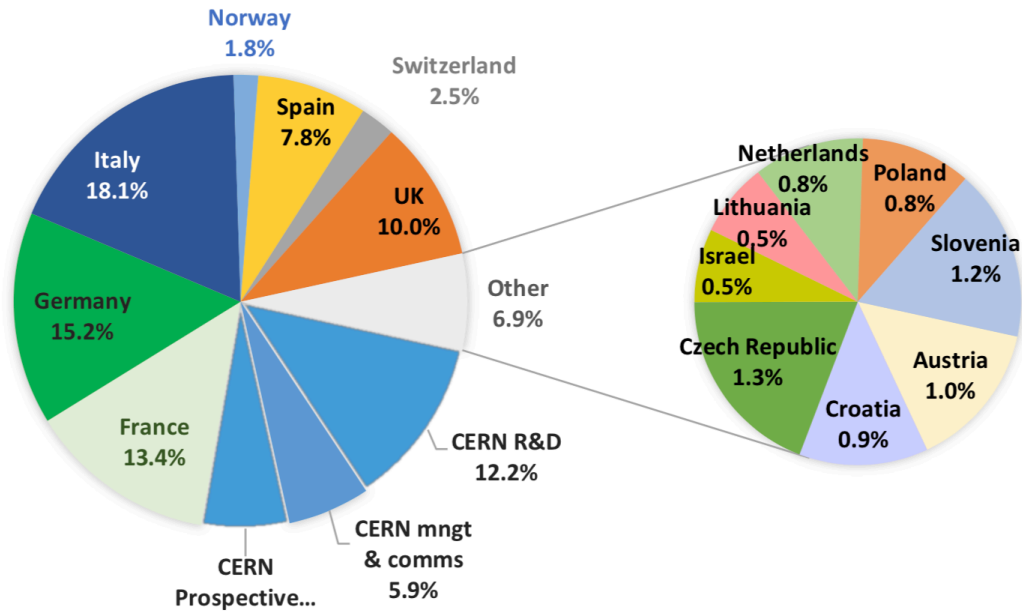


- The members of the Project Management Team and the Steering Committee will be approved by the Governing Board
- Scientific Coordinator: Felix Sefkow (DESY) + two Deputy Coordinators
- The Consortium is composed of 38 beneficiaries from 19 European countries

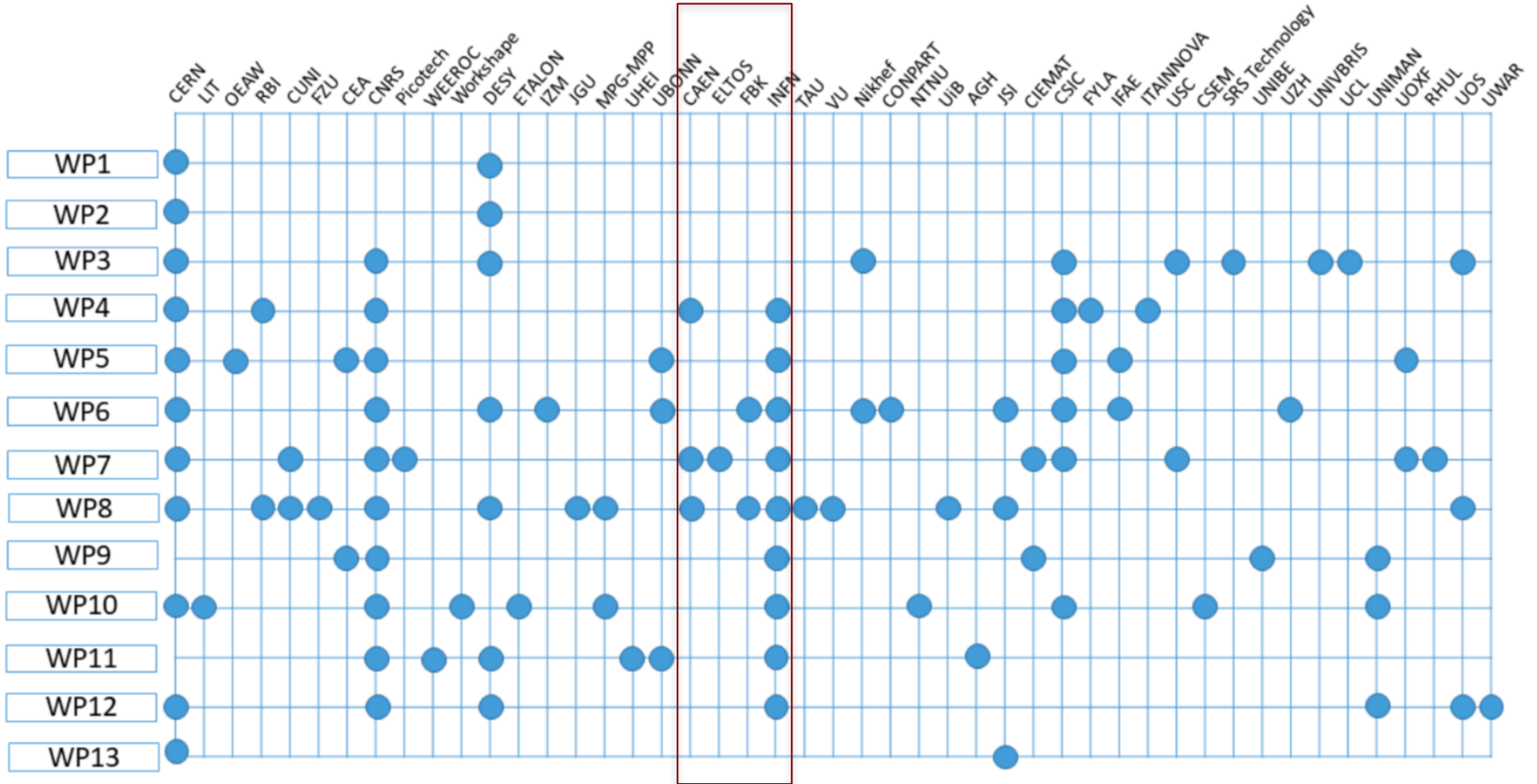
# Budget

Beneficiary no.	Beneficiary	Person-months	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (including overheads)
1	CERN	465.5	3,834,850.00	102,600.0	178,250.0	749,000.0	0.0	1,029,850.00	4,864,700.00	2,590,625.00
19	CAEN	53.0	227,900.00	12,400.0	22,000.0	0.0	0.0	34,400.00	262,300.00	162,500.00
20	ELTOS	12.0	72,000.00	7,000.0	50,000.0	13,500.0	0.0	70,500.00	142,500.00	87,500.00
21	FBK	23.4	154,440.00	20,220.0	9,000.0	157,000.0	0.0	186,220.00	340,660.00	218,750.00
22	INFN	586.0	2,930,000.00	120,000.0	125,000.0	27,000.0	0.0	272,000.00	3,202,000.00	1,345,000.00

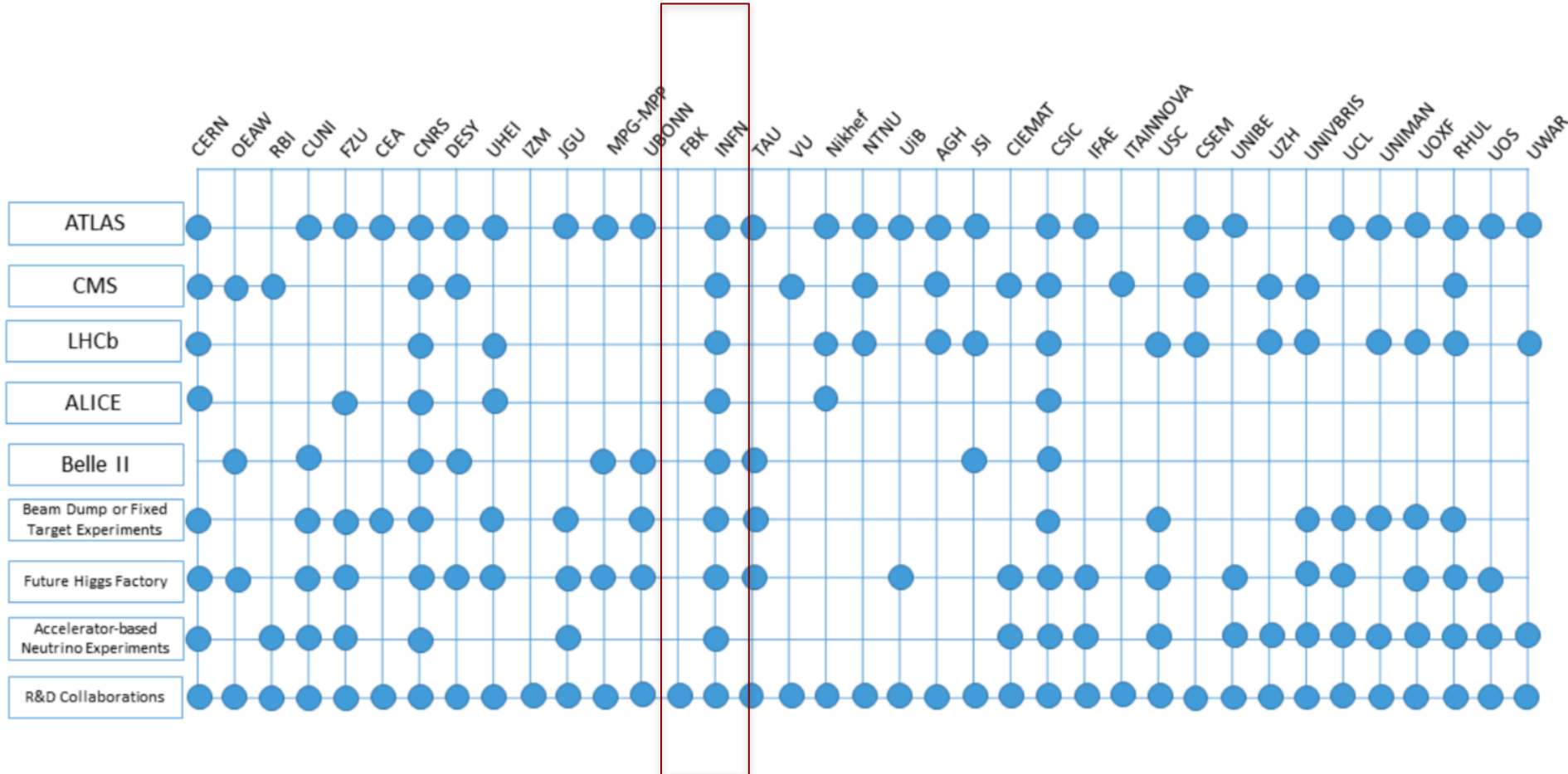
## EC FUNDING PER COUNTRY



# Italy



# Synergies





# Person-months

*funded by the EC and provided in-kind by beneficiaries*

No.	Beneficiary	WP1		WP2		WP3		WP4		WP5		WP6		WP7		WP8		WP9		WP10		WP11		WP12		WP13		Total PM per Participant	
		EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind	EC	in-kind
1	CERN	25.2	10.8	19.5	21.5	22.0	29.0	23.0	50.0	26.5	29.5	9.6	19.4	9.9	8.1	13.7	23.3	-	-	9.2	36.8	-	-	26.4	50.1	0.0	2.0	185.0	280.5
19	CAEN	-	-	-	-	-	-	11.0	9.0	-	-	-	-	11.0	10.0	6.0	6.0	-	-	-	-	-	-	-	-	-	-	28.0	25.0
20	ELTOS	-	-	-	-	-	-	-	-	-	-	-	-	11.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	11.0	1.0
21	FBK	-	-	-	-	-	-	-	-	-	-	17.0	0.0	-	-	6.4	0.0	-	-	-	-	-	-	-	-	-	-	23.4	0.0
22	INFN	-	-	-	-	-	-	5.0	12.0	19.5	39.5	24.0	53.0	62.0	119.0	24.0	35.0	6.0	12.0	4.0	8.0	44.0	77.0	14.0	28.0	-	-	202.5	383.5



**DOPO L'APPROVAZIONE DEL PROGETTO → per il 2021**

- Apertura della sigla in tutte le sezioni beneficiarie
- Dichiarazioni percentuali da rendicontare su timesheet
- Questa sigla dovrà essere considerata sinergica ai progetti coinvolti
- Preparazione bandi per personale finanziato (co-finanziato) dal progetto

**extras**

# INFN @ WP

WP		Industries	INFN
3	beam telescopes + DAQ @ CERN & DESY		
4	irradiation/EMC, characterization facilities	CAEN	<i>ENEA-FNG irradiation</i>
5	Depleted Monolithic Active Pixel Sensors		PI, TO, MI, PV, CA
6	hybrid silicon pixel including timing (4D)	FBK	CA, GE, PG, TN,TO
7	new gas detector MPGD, RPC,TPC	CAEN ELTOS	BA, BO, LE, LNF, PV, RM3, TS
8	calorimeters and particle ID detectors	CAEN FBK	BO,LNF,NA,PD,PG,PV,TO <i>Glass2Power</i>
9	cryogenic neutrino detectors: LAr TPC		MIB
10	advanced mechanics for ultra-light Sidetector		PI, PG
11	microelectronics: ASIC design		BA, BO, PV, TO
12	software/reco: Turnkey Software Stack		FE, PD, PI
13	prospective and technology-driven R&D		

# INFN @ WP

WP			Indus	INFN
3	beam telescopes + timing			
4	irradiation/EMC,	capire meglio - irraggiamenti	CAEN	<i>ENEA-FNG → RM1</i>
5	DAMPS	Belle2 ALICE Higgsfact/ATLAS		PI, TO, MI, PV, CA
6	hybrid silicon pixel (4D)	ATLAS – CMS – LHCb - Higgsfact – (Timespot)	FBK	CA, GE, PG, TN,TO
7	gas detector MPGD, RPC,TPC	ATLAS – CMS – LHCb – EIC – Higgsfact - neutrino	CAEN ELTOS	BA, BO, LE, LNF, PV, RM3, TS
8	calorimeters and particle ID	BELLE2 – KLEVER – Higgsfact – SHIP – LHCb – DUNE	CAEN FBK	BO,LNF,NA,PD,PG,PV,TO RM1MI PI <i>Glass2Power</i>
9	cryogenic neutrino: LAr TPC	DUNE → solo CSN2		MIB
10	advanced mechanics	ATLAS – CMS – BELLE2 – Higgsfact		PI, PG
11	microelectronics: ASIC design	all		BA, BO, PV, TO, MI, CA, FE, LNF
12	software/reco	all		FE, PD, PI, BA, RM3, BO,PV
13	technology-driven R&D	<b>Future to be discussed soon</b>		<b>12</b>

### **Task 4.1 Coordination and Communication**

*See introductory section on page 29.*

# WP4

### **Task 4.2 Micro-beam upgrade at RBI accelerator facility**

- Upgrade the RBI Accelerator Facility (RBI-AF) infrastructure for detector characterisation and radiation hardness studies at micron-scales, including the upgrade of the motorised precision device positioning, cooling and data acquisition systems

### **Task 4.3 Common tools for irradiation facilities quality control: data management, traceability, dosimetry and activation measurements**

- Generalise the IRRAD facility Data Manager (IDM) system to include new facilities (e.g., CERN GIF++, ENEA-FNG) and improve the sharing of irradiation experiment results and operational data
- Produce a common dosimetry calibration set for cross-comparison of irradiation facilities
- Design and develop the prototype for an integrated system to manage induced activation (gamma spectrometry) and traceability data for irradiated objects

### **Task 4.4 Design & development of a new sensor characterisation system based on the TPA-TCT technique**

- Complete the development from the proof-of-concept installation towards a customisable user friendly Two-Photon Absorption (TPA) Transient Current Technique (TCT) system with data acquisition and data analysis tools
- Support the evaluation of newly developed sensors (Low-Gain Avalanche Detectors and depleted CMOS devices) developed in WP5 and WP6
- Offer support towards the implementation of similar systems in other European institutions

### **Task 4.5 Design & development of new electronics characterisation system for EMC control**

- Design and develop an Electromagnetic Compatibility (EMC) test bench to measure the noise transfer function (TF) curves of physics detectors
- Design and develop a portable test bench to perform in-situ EMC emission measurements of power supply unit in irradiation facilities

## Objectives

### Task 5.1 Coordination and Communication

*See introductory section on page 29.*

# WP5

### Task 5.2. Development of high granularity DMAPS

- Design of test structures and high granularity monolithic devices meeting different requirements, specifically high position resolution, low material thickness and power consumption, in particular targeting experiments at  $e^+e^-$  colliders such as Belle II and Higgs factories. Two versions are planned, the second after evaluation of the performance of the first one
- Fabrication of test structures and high granularity prototypes in multi-project wafer runs (MPW) runs.
- Development of a readout and test system for the devices
- Characterisation of the devices in the laboratory and in beam tests before and after irradiation to medium doses and fluences

#### Subtask Design

- Design of monolithic pixel sensors with high spatial granularity

#### Subtask Characterisation

- Tests and characterising measurements of high granularity monolithic pixel sensors

### Task 5.3. Development of radiation hard DMAPS

- Design of test structures and radiation hard monolithic devices for applications in experiments with very high rate and high radiation levels, such as LHC Upgrades (e.g. for after long shut-down 4, LS4) or future hadron colliders
- Fabrication of test structures and a radiation hard prototype in a MPW run

- Development of a readout and test system for the devices
- Characterisation of the devices in the laboratory and in beam tests before and after irradiation to high fluence

#### Subtask Design

- Design of monolithic pixel sensors with high radiation tolerance

#### Subtask Characterisation

- Characterisation of monolithic pixel sensors with high radiation tolerance

## Objectives

### **Task 6.1. Coordination and Communication**

*See introductory section on page 29.*

### **Task 6.2. Simulation and processing of common 3D and LGAD sensor productions**

- Optimisation of processes for 3D and LGAD sensors for timing applications
- Simulations of various designs for 3D and LGAD sensors to compare and optimise the layout in terms of timing performance
- Simulations of surface and bulk radiation damage for 4D (tracking+timing) detectors toward more radiation tolerant solutions
- Processing of two common 3D sensor productions and two common LGAD productions by FBK/CNM
- Design and implementation of simulation software which is applicable to a large range of technologies and includes models for the description of effects from sensor level to readout electronics in semiconductor detectors

### **Task 6.3. Validation of common 3D and LGAD sensor productions**

- Characterisation of the 3D sensors in terms of timing, radiation hardness, efficiency and uniformity via measurements in the laboratory and beam tests
- Characterisation of small pitch LGAD and inverse LGAD sensors (iLGADs) from the common production in terms of timing and efficiency via measurements in the laboratory and beam tests
- Feedback to the foundries for further process optimisation of 3D and LGAD sensors

### **Task 6.4. Development of interconnection technologies for future pixel detectors**

- Development of suitable Anisotropic Conductive Films (ACF) material and die-to-die bonding process flows for small pixel pitches
- Production and post-processing of dedicated planar sensor wafers for ACF trials
- Test of the performance of sensor modules interconnected with ACF
- Production and test of ultra-thin assemblies interconnected with a wafer to wafer bonding technology
- Post-processing of sensor prototypes developed in Task 6.3

**WP6**

### **Task 7.1. Coordination and Communication**

*See introductory section on page 29.*

### **Task 7.2. Multigap RPCs (MRPCs) for fast timing and Eco-friendly gas mixtures for RPCs**

- Developing and testing material (thin plates of low resistivity glass)
- Construction, characterisation and test beam of small-size prototypes
- Construction of  $1 \times 1 \text{ m}^2$  prototypes with the new readout plane structure for a semi-digital hadron calorimeter (SDHCAL)
- Test beam study of the shower time development in an SDHCAL, equipped with the prototype detectors
- Identification and characterisation of new gas mixture candidates
- Validation of the gas mixtures after large integrated doses at GIF++

### **Task 7.3. Development of resistive electrodes for MPGDs and Industrial engineering of high-rate $\mu$ -RWELL detector**

- Production of Diamond Like Carbon (DLC) with ion beam deposition and pulsed laser deposition
- Study of the resistance of graphene to polyimide etching liquids
- Characterisation of  $10 \times 10 \text{ cm}^2$  foils by DLC and graphene
- Industrial production of small-size prototypes and their characterisation
- Industrial production of large-size prototypes ( $\sim 0.5 \text{ m}^2$ ) and their characterisation

### **Task 7.4. A 4-channel electronic board prototype for cluster counting and Hybrid readout for high pressure gas TPC for neutrino physics**

- Design electronics and realise a 4-channel prototype for cluster counting in ultra-light drift chambers
- Identification and characterisation of adequate gasses
- Construction of a small-scale TPC prototype ( $\sim 10 \text{ l}$ ) with a hybrid charge and optical readout

### **Task 7.5. Photon detectors for hadron particle identification at high momenta**

- Development of MPGD single photon detectors for compact Ring Imaging Cherenkov detectors
- Comparison of measured prototype characteristics with Silicon Photomultipliers (SiPMs) and Large Area Picosecond Photodetectors (LAPPDs)



## Objectives

### **Task 8.1. Coordination and Communication**

*See introductory section on page 29.*

# WP8

### **Task 8.2. Towards next generation highly granular calorimeters**

- Development of a common electromagnetic and hadronic calorimeter data concentration interface for minimised space and power consumption
- Demonstrator with functional active detector elements and full read-out chain
- Development of a high granularity demonstrator for Liquid Noble gas calorimeters with innovative readout technologies

### **Task 8.3. Innovative calorimeters with optical readout**

- Optimisation of crystal materials and processes for fast timing applications in radiation environments
- Industrialisation of the production process of fast and radiation-hard crystals
- Study of neutron detection with organic scintillators
- Develop scalable production procedures for large-scale highly granular scintillator calorimeters

### **Task 8.4. Innovative solid-state light sensors and highly-granular dual-readout fibre-sampling calorimetry**

- Systematic study of neutron irradiated SiPMs at different temperatures
- Development of SiPMs with improved radiation resistance
- Definition of the specifications for an optimal ASIC and the readout for fibre-sampling dual-readout calorimeters
- Construction of several  $10 \times 10 \text{ cm}^2$ , 2 m long, dual-readout matrices with SiPM sensors and readout electronics

## Objectives

### **Task 10.1. Coordination and Communication**

*See introductory section on page 29.*

### **Task 10.2. Engineering of optimised cooling substrates**

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# WP10

INFRAINNOV-04-2020

AIDAinnova

- Develop the process of cooling channel integration in CMOS structures into scalable solutions
- Define the optimal geometrical features attainable for 3D printed ultra-thin cold plates in metal alloys and ceramic composites
- Implement the full integration of cooling features into ultra-light carbon composite structures

### **Task 10.3. Micro-connectivity**

- Define advanced engineered solutions for the hydraulic interconnection of multiple micro-structured silicon cold plates

### **Task 10.4. Supercritical CO<sub>2</sub> as refrigerant**

- Characterise Supercritical CO<sub>2</sub> (sCO<sub>2</sub>) as a possible ultra-effective single-phase refrigerant for “warm” detector cooling
- Study the design of new supercritical heat exchangers for optimal energy recovery at higher temperatures in transcritical CO<sub>2</sub> cycles

### **Task 10.5. Characterisation of ultra-light structures**

- Evaluate the feasibility of a new version of the existing Frequency Scanning Interferometry (FSI) instrumentation suited for use as an accurate survey of ultra-light and small detector structures
- Refine and standardize the methodology for vibration and distortion measurements in view of new and more precise specifications for future detectors

# WP11

## Objectives

### **Task 11.1. Coordination and Communication**

*See introductory section on page 29.*

### **Task 11.2. Exploratory study of advanced CMOS (28 nm)**

- Explore advanced 28 nm CMOS for future trackers
- Qualify radiation tolerance
- Design and test front-end prototype ASIC

### **Task 11.3. Networking and ASICs for other WPs (65/130 nm)**

- Cold and timing ASICs in 65/130nm CMOS
- MPGD readout ASICs
- Silicon and SiPM readout ASICs for future colliders and timing applications

## Objectives

### **Task 12.1. Coordination and Communication**

*See introductory section on page 29.*

### **Task 12.2. Turnkey Software**

- Integrated Turnkey Software Stack, for physics and performance studies
- Simplified data model toolkit for modern hardware platforms
- Digitisation extensions for geometry toolkit
- R&D study on frameworks to manage heterogeneous resources

### **Task 12.3. Simulation**

- Fast simulation techniques integrated into Geant4
- Machine learning based calorimeter simulation toolkit for training and inference

### **Task 12.4. Track Reconstruction**

- Develop complete track reconstruction chain with Acts composable algorithms
- Implement a portable version of Acts algorithms, for heterogeneous computing
- Machine learning reconstruction algorithm for MPGD detectors

### **Task 12.5. Particle Flow Reconstruction**

- Advanced PFA algorithms for DUNE detectors using new readout technologies
- PFA algorithm with particle ID for dual-readout calorimeters
- Optimised APRIL PFA algorithm for hadronic jets

# WP12

# WP13

## Objectives

### **Task 13.1. Coordination and Communication**

- Define and supervise the selection procedure for the generic R&D projects
- Establish the connection to the Management and the communication with other WPs
- Manage the administrative, financial and IPR aspects of the projects

### **Task 13.2. Follow-up and Evaluation**

- Monitor the progress of individual projects and ensure regular reports to the community
- Evaluate the results and the effectiveness of the supporting measures