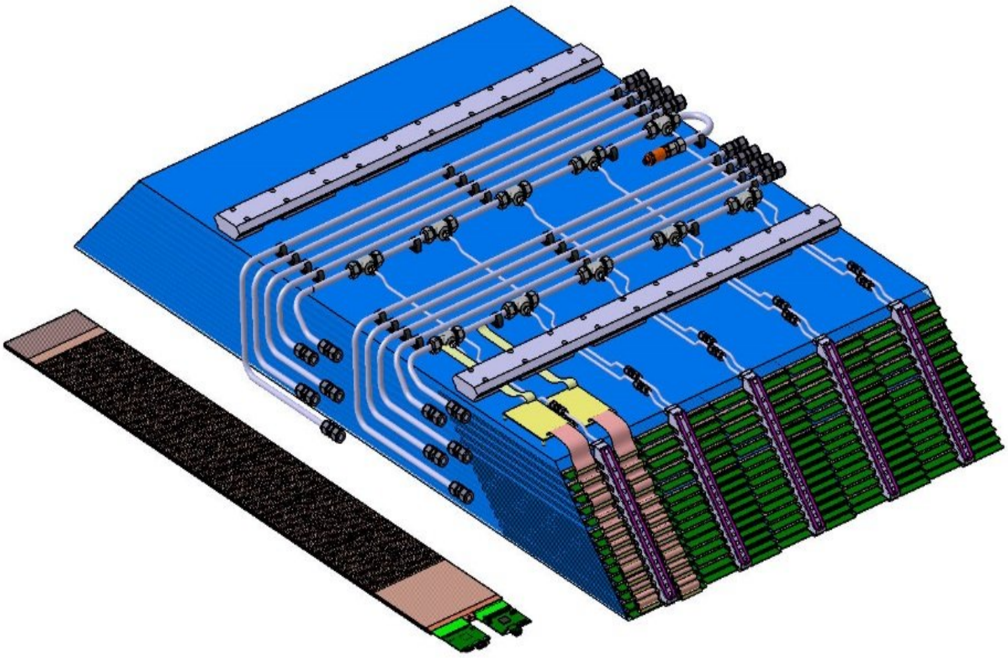
Institut national de physique nucléaire
& de physique des particules

Fiche projet de R&T

SiW-ECAL/Vincent Boudry



Réf Interne :	Référence interne laboratoire
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Titre / *Title* :	Fiche Projet SiW-ECAL
Résumé / *Summary*:	Description du projet de développement d'un calorimètre Silicium-Tungstène très granulaire, adapté aux détecteurs orienté Particle Flow pour les futurs collisionneurs e+e-.

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Suivi du document */History*

VERSION	DATE	HISTORY MODIFICATION	PAGES CHAPTERS
1	07/02/2020	Création du document	Tous
2	06/01/2021	Mise à jour du document : • Ajout d'un avertissement • Renforcement des exigences de publication • Ajout d'un chapitre qui contiendra les références des documents principaux produits dans le cadre du projet (hors publications) • Corrections de quelques typos	Pages liminaires Ch. 8 Ch. 9 Ch. 10

Acronymes/*Acronyms*

CS : Conseil Scientifique de l'Institut

CSL : Conseil Scientifique Laboratoire

ETP : Equivalent Temps Plein

TRL : Technology Readiness Level

Acronymes à rajouter si utilisés dans le document

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Tableaux/*Tables*

Thématique du projet

Thématique(s) adressée(s) par la Th&Ph *(au sens des thématiques Th&Ph IN2P3)*
✔ Particules et Hadronique (PH) ☐ Astro-particules et Cosmologie (AC) ☐ Accélérateurs et Technologies (AT) ☐ Data & Computing (DC) ☐ Nucléaires & Applications (NA)

AVERTISSEMENT

Cette fiche constitue la « mémoire » du projet. Elle est rédigée initialement lors de la soumission du projet et signée par les directeurs des unités concernées par le projet pour validation. Elle est ensuite mise à jour chaque année à l'automne pour tenir compte de l'avancée du projet, des changements éventuels de périmètres, des consommations réelles de ressources financières et humaines ou enfin du calendrier. Elle est aussi mise à jour lorsque les partenaires du projet évoluent (nouveau laboratoire ou laboratoire partant).

Dans le cas d'une évolution des ressources humaines ou de l'arrivée d'un nouveau partenaire la fiche devra être validée à nouveau par les DUs concernés.

1 Objectifs du projet

1.1 Objectifs technologiques

The Particle Flow approach (PFA) combining precision tracking, highly granular calorimetry and advanced algorithms, is a promising path toward higher performances of experiments near future e+e- Higgs/EW/Top factories. By distinguishing the contribution of each particle reaching the calorimeters, and its substitution by a track measurement for the charged ones using a geometric matching, a considerable improvement of the jet energy resolution can be obtained. The PFA is especially powerful in the low and medium energy jets, as expected from most heavy decays and for almost all collision energies. The foreseen centimetric size of the readout cells in the calorimeters is also ideal for precision timing measurement (1 cm/c = 30 ps), useful for particle identification e.g., using time-of-flight (ToF) measurements and background rejection (pile-up of events and backscattering particles). The large number of cells allows for redundancy and systematics reductions.

Highly-granular calorimetry are complex devices facing many technological challenges involving mechanics, thermal management, electronics, and instrumentation. The high-granularity implies the readout of $\mathcal{O}$(100M) channels for a complete experiment, hence a low-power, embedded very-front-end electronics, and the building of $\mathcal{O}$(100k) elements, hence a scalable design. The PFA performances will also rely on a global blueprint minimizing dead-spaces, but mechanically sound, while ensuring the integration of DAQ and cooling services. For cost and performance effectiveness, the calorimeter system is divided in a front (ECAL) and back (HCAL) parts.

This project aims providing a SiW-ECAL using silicon sensors, and tungsten as an absorber, with a design compatible with the experiment concepts collaborations near future colliders (ILD, SiD, CEPC baseline, CLD, CLICdet), based on tested functionnal technological prototypes.

(½ page maximum)

1.2 Cadre scientifique

Dans le cas où le projet est rattaché à une thématique scientifique, décrire le contexte. Décrire également si nécessaire le contexte national/international de la problématique envisagée.

The developments are made in two separate, but strongly connected, spaces: one for the detector concepts for experiments near different collider projects, and one the intrumental work.

For the conceptual work: complete design and simulation models of the SiW-ECAL have been made for the **ILD** concept for the ILC by the French and Japanese participating teams[1]. Simplified versions of ILD have been adapted for the **CLICdet** for the CLIC, themselves later recycled for the **CLD** concept for the FCC-ee. The ILD design has been modified for the CECP "baseline" detector.
In practise, the original design optimised for the pulsed mode of the linear colliders (ILC, CLIC), needs a complete revision for the continous running of circular colliders (FCC-ee, CEPC) in term or rates, power dissipation and acquistion mode, and the design a new readout electronics and possibly a new cooling system. This work is done in the framework of the detector concept groups, linked to the global

[1] A concurrent design was made in the USA for the SiD concept.

development groups of the FCC, Linear Collider Collaboration (LCC) and the CEPC, and regularly presented in each of the workshops.

The instrumental work: Many prototypes of detector elements of the SiW-ECAL have been gradually developped in the framework of the **CALICE** collaboration, with a strong, but decreasing, financial support from the European Detector R&D programs (EUDET, AIDA, AIDA-2020, AIDAinnova). This intrumental work is will be integrated in the DRD6 collaboration in the making.

(½ page maximum)

1.3 Estimation du TRL (Technology Readiness Level)

Dans ce chapitre figure l'estimation du TRL de départ, du TRL courant (avancement du projet) et du TRL final. La métrique est décrite ci-après.

Niveau	Définition	Nom synthétique
TRL1	Principes de base observés et identifiés	Principe de base
TRL2	Concept technologique et/ou application formulés	Application formulée
TRL3	Preuve du concept analytique et preuve expérimentale de la fonction et/ou de la caractéristique critique	Preuve du concept
TRL4	Vérification fonctionnelle en environnement de laboratoire au niveau composant et/ou maquette	Validation fonctionnelle
TRL5	Vérification en environnement représentatif de la fonction critique au niveau composant et/ou maquette	Modèles à échelle réduite
TRL6	Démonstration en environnement représentatif des fonctions critiques de l'élément au niveau modèle	Validation de la conception
TRL7	Démonstration en environnement opérationnel de la performance de l'élément au niveau modèle	Qualification d'un modèle
TRL8	Système réel développé et jugé apte à l'expérience	Qualification du système réel
TRL9	Système réel ayant été utilisé à l'identique et avec succès lors d'une expérience dans l'environnement idoine.	Opération du système réel

Echelle des TRLs (définition basée sur la norme ISO 16290:2013)

1.3.1 TRL initial : *(colorer la case correspondant à votre TRL initial)*

	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
Sensor									✔
ASIC							✔		
PCB (FEV)			✔						
ASU		✔							
SLAB		✔	✔	✔					
Structure		✔	✔	✔					
DAQ									✔
Power			✔						
Cooling							✔	✔	✔
Design		✔							
Prototypes			✔						

Donner ici un argumentaire synthétique étayant votre estimée du niveau de maturité technologique.

The SiW-ECAL is the most advanced option of calorimeters in its **design**, for future Higgs Factory experiment concepts, while facing the strongest challenges in terms of compactness and cell density (compared with HCALs). Silicon sensors offer very stable operation, a good instrumental performance for sandwiched calorimeters, and a solid industrial base for large production. Tungsten allows for both compact showers, hence a better separability, and mechanical support.

The **sensor** design in 6'' dimensions has been improved to reduce the capacitive cross-talk through the floating guard rings observed on the physical prototype and cold be used for large scale production. They will be used for the LUXE experiment.

We have now a composite **prototype** of 15 layers[2], each incorporating a single Assembly Single Unit (ASU, the base assembly detector unit of the SiW-ECAL, measuring 18×18 cm²). An **ASU** is composed of a Front-End **PCB** (FEV), supporting 16 **ASICs** and their ancillarity components on one side, and 4 silicon **sensors** glued on the other side. Up to 8 (12) ASUs must be chained to form a **SLAB** in the barrel (endcaps).

In 2021 and 2022, stacks of 15 layers of single ASUs have been tested in beam at DESY and CERN, demonstrating good key performances: a bulk signal-to-noise ratio, defined as the most-probable-value of a MIP to the pedestal width, of 12 in the trigger branch (and 20 in the high-gain readout branch) beyond the requirement of 10 from the experiments, a good uniformity of response spatially and in time (memory). The high-energy response is being analysed; preliminary results are encouraging, despite the observation of collective effects for very dense showers, linked to HV distribution. In 2019, a model-slab of 8 ASUs partially equipped was also operated successfully in beam at DESY but has shown the necessity of a better regulation of the LV distribution to mitigate a small drop of gain along the slab. Finally, we recently have

[2]The final detector aims 26 to 30 layers.

experienced the side delamination of some sensors from their PCB. Investigations and tests are going-on, to improve the gluing and assembly processes of the ASUs.

This prototype was operated by a compact **DAQ** nearly compatible with the ILD design.

The current composite prototype includes **ASUs** with 3 versions of FEV and 3 silicon sensor thicknesses. The construction of a small uniform **prototype** is well advanced, but requires the validation of final design of the front-end (**PCBs** and **ASICs**) and its associated **DAQ** in beam.

A new version of the **PCB**s, including a revised **powering** scheme for low voltage (regulators) and high-voltage (on-board filtering) and monitoring is being produced.

A large prototype of a tungsten-CFRP **structure** was produced. Its dimensions and composition (60 cm×1.5 m, 3 towers of 15 alveoli), are representative of the ILD baseline for the barrel (90 cm×1.8 m, for 5 towers of 15 alveoli). It is instrumented with Fibres Gragg-gratted. The static metrology was almost satisfying, but must be completed at various orientations, to be compared with simulations. Alveoli of larger dimensions (2.5 m), representative of the ILD endcaps, were built in the industry.

A prototype of a leakless water **cooling system** was built and operated in two parts: 1) as scale 1:1 loop as expected from the ILD ECAL, and 2) as a caloduc mounted on the tungsten-CFRP structure equipped with heating slabs. Both fulfilled the requirements to operate the ILD SiW-ECAL il the ILC baseline operation.

The current **ASIC**s have been build on blocs which have been proven and reused; they used a technology soon to become obsolete and will require a refactoring to include an upgrade of the performances and the handling of continous operatio for circular colliders.

1.3.2 <u>TRL courant :</u> *(colorer la case correspondant à votre TRL actuel)*

	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
Sensor									✔
ASIC							✔		
PCB (FEV)			✔						
ASU		✔							
SLAB		✔	✔	✔					
Structure		✔	✔	✔					
DAQ									✔
Power			✔						
Cooling							✔	✔	✔
Design		✔							
Prototypes			✔						

Donner ici une description et une justification synthétique du niveau de maturité technologique que vous avez obtenu jusqu'à présent.

Just starting so same as TRL Start.

1.3.3 <u>**TRL final :**</u> *(colorer la case correspondant à votre TRL final)*

	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
Sensor									✔
ASIC							✔		
PCB (FEV)			✔						
ASU		✔							
SLAB		✔	✔	✔					
Structure		✔	✔	✔					
DAQ									✔
Power			✔						
Cooling							✔	✔	✔
Design		✔							
Prototypes			✔						

Donner ici une description du niveau de maturité technologique que vous comptez avoir en fin de projet.

2 Description des taches - responsabilités - organisation

Ici sera présenté de manière synthétique (maximum 15 lignes), le plan de développement (ou méthode) pour atteindre les objectifs présentés dans le chapitre 1.

Préciser la durée attendue du projet (en mois).

The work presented here covers the next 3 years (end of 2026), with the main objective at this date to establish a design, assembly methods, time and cost estimates, firmly based on prototypes construction and testing. This design includes the devlopment a new ASIC branch.

Three work development axes are defined:

1. re-evaluation of the working conditions for all the Higgs factories, and provide one or several designs, suitable for all conditions.
2. the exploration of the potential of improved timing in the SiW-ECAL for Particle ID and Particle Flow.
3. the construction of a uniform prototype to ensure the technical feasibility, and provide a reference sample to adjust the Geant4 simulation; this prototype finds practical applications after smal adaptations in one or several experiments in extreme QED and search for Axion-like particles.

This design will serve as the basis for the construction of a pilote module, a mandatory milestone before the building of the full detector. The starting date of the pilote module is highly dependent on the choice (type and agenda) of a Higgs factory. Its building can take up to 5 years, while the detector ke another 8 to 9 years.

2.1 Description des travaux techniques

Liste, articulations et descriptions techniques des tâches et des travaux.

2.1.1 Adaptation to the FCC conditions:

The global design of the SiW-ECAL is almost universal to all Higgs factories, all presenting a low background, low radiation and a low calorimetric occupancy. They differ in the operation modes, pulsed at current linear colliders, continuous for circular ones. The pulsed mode allows for a large gain (~99 %) on power dissipation in the detector, and the use of a passive cooling. For continuous operation, the ILC design can be adapted following two compatible options:

1) Reducing the power by a lower granularity and by the electronics design,
2) Implementing an active cooling (e.g., dual phase CO_2) in the ECAL modules.

The active cooling brings complexity, extra materials and possible non-uniformities, all detrimental to PFA performances, and should be avoided if possible. Fortunately, the electronics design has improved.

2.1.1.1 Power Budget

The allowable power budget has to be evaluated from the collider's conditions (luminosity, backgrounds) and physics simulations, for various electronics hypothesis, to establish the ASICs and ECAL specifications.

The consumption can easily be modelled from physics simulation and hypothesis on the electronics (base consumption, precision, timing) for different configurations (number of layers, granularity).

The performance of the full system is more challenging, as it has to be evaluated in terms of physics estimators (jet and photon energy resolution, tau-identification, tagging, …) after a full reconstruction, which has to be tuned for each configuration.

2.1.1.2 Electronics:

The current electronics (SKIROC2, 2a) has been developped a while ago (2012) with a technology (AMS035) becoming obsolete. In collaboration with the CEA and AGH Kraków, the Ωmega Team proposes to exploit the gained experience from the HGCROC and the HKROC ASICs, children of the SKIROC in TSMC 130 nm. Sharing a common interface and having dedicated front-ends, a new range of ASICs could fulfill the needs for (almost) all Higgs factories calorimeters (and the EIC's) : working in self-trigger mode – adapted to the expected low occupancy – with a power consumption per channel reduced to a few mW.

The first development runs, dedicated to the testing of the Front-End part, are foreseen in 2024 for the EICROCs and DRD6ROCs. A second run will follow, 12 to 18 months later, to include the interface, common to all ASICs. This first version ASIC (v1) will have to be tested thouroughly on a bench and integrated on a PCB. A second version (v2) will probably be necessary, prior to the lauching of a large scale procedure.

This work will be done in collaboration with this MP.

The DAQ and the Front-End board will have to be adapted accordingly,

2.1.1.3 Active Cooling

If the power budget exceeds the passive cooling capacity, with a safety margin, or that the extra-feature (e.g., timing) overweight the drawbacks of an active cooling, a **cooling R&D** will have to be started on a design (uniformity, thinness, reliability, integration) to minimize them.

2.1.1.4 Mechanical structure

The characterisation work on the W-CFRP mechanical structure has to be completed in order to fully assess this solution, and the cross-check of mecahnical simulations.

The fibre's readout requires a specific (and expansive) reader and was never implemented.

2.1.1.5 Far side plans (beyond 2026):

The development of the activities beyond 2026 will depend on political choices beyond the horizon. A landmark is the ESPP in 2027; but less certain events can happen before: decision to host the ILC from Japan is less likely but not (yet) fully excluded, the next 5-year Chinese plan starting in 2026 could include the CEPC (ranked 1st of the future large science facilities in particle and nuclear physics large in China by the CAS IAC in december 2022). This renders the planning uncertain, and requires the French group to stay ready to get engaged in the first (and probably single) approved project.

The construction of a calorimetric system typically takes 8~9 years. Subtracted from the machine start date to mark the end of engineering studies, this gives 2036 for the FCC-ee (in 2045), but 2031 for an ILC (in 2040) or even earlier for an CEPC.

2.1.1.5.1 Design of a Pilote Module

A key achievement of the engineering studies should be the realisation of a pilote module, large enough to be representative of the final detector building units. Typically, this would be a module of 1/60th of the detector, for one million channels, with all services. It should be built by a semi-industrial construction organisation in close link with industrial partners. This requires in turn that the leading laboratories to have acquiered the related competences (project management, quality chain building, etc). For these, we can partially capitalise on the experience from the HGCAL construction, but the scale of the project must involve new professional know-how in production.

The building of such a module takes 5 to 6 years, each testing a complete scale with increasing needs in manpower and materials: ASIC, ASU/SLAB, Tower, Module. For the later stages, a close collaboration with industrial partners (sensors, connectors, assembler) must be carefully planned.

The first stage is the development of a suitable ASIC. We can capitalize on the developments made by the Ωmega group for the HGCAL (HGCROC) and the HyperKamiokande (HKROC) in the TSMC130nm technology. This technology seems to be a good compromise between novelty, perenity, power efficiency and costs of production.

Where a consequent funding can only for the pilote moudle be for envisaged once a collider projet has been endorsed, probably during the ESPP revision in 2027, the R&D on the building blocs of ASICs must start very early to explore the technological limits, and integrate them in the global detector design. The design of the building blocks could start as early as 2024, as they can be re-employed in several other projects (ℓAr, EIC, …). The testing of the building blocks would allow laying solid fundations for the revised design of a future SiW-ECAL.

2.1.1.5.2 Beyond High Granularity.

Beyond this classical approach decribed above, higher granularities, eventually push to the limit of a fully **digital calorimetry**, are part of longer-term plans. These will highly depend on the time available for R&D before construction start, and on innovations from DRD7, DRD4 and DRD3.

2.1.2 Timing

Among the additional specifications, the measurement of the timing of the showers in the SiW-ECAL offers a large instrumental potential.

With precisions around the ns, event pile-up, backscattered particles and the late neutronic component can be tagged. With a precision few 10 ps, the particle Time-of-Flight, especially useful for low-velocity particle, complements the dE/dx of the tracker for particle identification.

Two paths can be followed:

1) a few dedicated high-precision timing layers, at the entrance and centre of the ECAL, with fast sensors (e.g., LGADs),
2) a moderate timing in the bulk of the ECAL, the precision being recovered by adequately combining the timing of cells of the shower, if careful clock distribution is performed.

For the option 1) a specific electronics and design must be developed and tested. For the option 2) a precision of $\mathcal{O}$(100 ps) for a mip per cell seems achievable, but might be limited by the power budget.

An improved precision of the bulk timing would also bring benefits for the PFA, by easing the reconstruction. This is being tried in the APRIL algorithm. Feeding this additional information to a reconstruction using machine learning could also bring positive surprises. The full development of timing, in the ECAL, goes already beyond 2026.

2.1.3 Prototypes

The prototype tests in beam in 2021 and 2022 have brough very valuable information: calibation procedure for a self-triggered electronics, the first response to low- and high-energy particles with this kind of granularity. But due to the development process and limited funding, the prototype was built gradually and now includes 4 types of boards and 3 thickness of sensors. We see some aging effects partly due to the manipulation.

In 2023, an improved version (v2.1) of the PCBs for BGA-type is being produced, which includes voltage regulators, HV supply and filtering, and better clock distribution. The preliminary measurements show a much improved uniformity and stability of the ASICs operations. The design was also made modular to allow for testing in different configurations. Ideally the setup will also allow for the use of the TDC, providing a timing with a ns resolution at the mip level, in the full calorimeter (now only couple of layers can use it).

2.1.3.1 Uniform 15-layer stack

For 2024, using the new boards and existing hardware (sensors, ASICs, components), a homogeneous and compact stack of 15 layers will be built. It will benefit also from a full testing of the ASICs prior to soldering, and a revised sensor gluing procedure. After commissioning with sources and cosmics, it will be put in beam in 2024, standalone and with AHCAL. The support from EUROLabs for the missions will be requested.

The data collected with the new stack will serve several goals:

1) the operation of a robust set-up in beam, suitable as a basis for a realistic simulation of the concepts of experiments, and testing of PFA and ML on real data;
2) it will provide a reference sample to tune the simulation. With lateral granularity 4 times that of the previous sample ('physical prototype') or the HGCAL, a simple geometry, a trigger level at a fraction of a mip, allowing particle tracking, and a timing in every cell, this sample is potentially very rich;
3) It will complete one of the AIDAinnova deliveries in a timely manner.

Using the same material, a stack of 7 double-ASU slabs will provide valuable information at the interface between board, and pave the way to some direct applications (c.f. next section). The collected data will confirm the technical feasibility of the SiW-ECAL and be useful for applications.

The production of 15 ASU is ongoing with many activities in parallel: Sensor testing, PCB production, metrology, and cabling, HV Kpaton production, gluing improvement, DAQ adaptation, SLAB building, mechanical structure adjustments.

The goal is to provide the 15 layers in Q1 2024 for a beam test campaign.

Important Notice: *in the latest CERN PS and SPS Medium Term Plans*[3]*, the LS3 has been extended, to cover 2026 to almost all of 2028. During the same period, the DESY and FNAL beam test facilities might also be shut-down.*

2.1.3.2 Applications in experiments

The prototypes can have some direct usage for several fixed target experiments.

The LUXE experiment near XFEL at DESY aims at measuring non-linear QED Compton and pair production starting in 2025. The beam conditions comparable to ILC's would be a perfect fit for the current electronics. Then, various small-scale experiments looking for dark photons (LUXE at XFEL, EBES at KEK, Lohengrin at ELSA) could also almost directly use the SiW-ECAL prototype. Beside their intrinsic physical interest, running the device in such experiments during couples of months will bring invaluable instrumental experience with composed slabs.

The **LUXE experiment**[4] is a structured collaboration for which two highly ganular calorimeters are needed. One will be based on the design of the FCAL collaboration, the second will be the SiW-ECAL.

The time structure of the collision is very similar to the ILC, for which the current electronics has been specified. The energy of the electrons also do not exceed 17 GeV, and they have to be separated from background photons, cases for which the SiW-ECAL should perform very well.

With the additional purchase of 40 sensors, another 10 ASUs could be equipped.
The 7 double-ASU layers completed to 24 functional ASUs, a stack of 12 double-ASU can be mounted to cover ~2/3rd of the lateral acceptance of the LUXE experiment. A third tower would require heavier investments (new ASIC production, Tungsten and Sensors purchase).

The **lohengrin**[5] experiment aims at searching for dark photons and light dark matter, by looking at exotic bremstrahlung-like signal from an electron beam hitting a thin target. A high granularity ECAL is required to identifiy the scattered, low energy electrons and photons. The expected rates are high and will require some adaptations of DAQ.

The **EBES** (Electron Beam-dump Experiment at KEK Switching-yard 3) will use an extraction line of KEK linac supplying electron/positron beams to Super-KEKB (and photon factory). The main target is (Sub-GeV) ALP ➞ 2 photons. The beam comes with 25 Hz with a single bunch, having up to 2 pC. The beam energy is 7 and 4 GeV.
Detectors are not fully determined, but baseline is Silicon (as pre-shower and a few first layers) and Lead-glass calo. Optionally we will place full silicon stack in the middle of the aperture (if we get some budget for it).

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3 https://indico.cern.ch/event/1286143/contributions/5417292/attachments/2654479/4596869/IEFC-MTP-May23.pdf#page=11

4 https://luxe.desy.de/
H. Abramowicz et al., *Conceptual Design Report for the LUXE Experiment*, Eur. Phys. J. Spec. Top. 230 (2021) 2445–2560. https://doi.org/10.1140/epjs/s11734-021-00249-z

5 J.-E. Heinrichs, 'Lohengrin - An Introduction to Dark Photon Detection', CALICE meeting, Orsay&Palaiseau, Oct 2022.

2.2 Responsabilités

Qui fait quoi ?

WP1 Design for ee-Colliders :

WP1.1 Reporting & organisation : *V Boudry (LLR)*

WP1.2 Definition of requirements: *V. Boudry (LLR)*

WP1.3 Electronics: *Ch de la Taille (Omega), D. Breton (ICJlab)*

WP1.4 Cooling & Power: *Th. Pierre Emile (LLR)*

WP1.5 Structure / MDI: *Th. Pierre-Emile (LLR) / A. Gallas (IJCLab)*

WP1.6 Beyond 2026: *V. Boudry (LLR)*

WP1.6.1 Determination of a blueprint for a pilote module.

WP1.6.2 Beyond High Granularity

WP2 Timing:

This work package has been detailled in ANR proposals.

WP2.1 Organisation / reporting : *V. Boudry (LLR), R. Poeschl (IJClab)*

WP2.2 Inclusion in PFA: *H. Videau (LLR)*

WP2.3 Simulations: *Post-Doc LLR*

WP2.4 Dedicated layers: *T. Suehara (Kyushu)*

WP2.5 Performances: *J.C. Brient (LLR), R. Poeschl (IJClab)*

T1 Evaluate the performances for touchstone physics channels

WP3 Prototypes

WP3.1 Uniform prototype with 15 layers : *R. Poeschl (IJClab)*

WP3.1.1 **Sensors** : *A. Irles(IFIC) ? R. Cornat (LPNHE) ? E. Sicking (CERN)*

T1 *purchase* have so far been done by every group, depending on the available funding, by global commands near Hamamatsu.

T2 Tests have been performed in LLR and LPNHE. The CERN and FIC valencia has some capacity in testing samples.

WP3.1.2 **PCB:** *J. Nanni (LLR)*

T1 *Design* and *production* will be made by the LLR, with contributions from the IJClab;

T2 the *metrology* of the naked PCBs will be performed at the IJClab;

T3 the *cabling* will be done at IJClab;

T4 the *functionnal test* of the equipped PCBs will be performed at IJClab and LLR;

T5 The *metrology* of the equipped PCB will be performed at IJClab and IFIC

WP3.1.3 **Kaptons :** *J. Jeglot (IJClab), J. Nanni (LLR)*

T1 *design* has been made by the IJClab.

T2 purchase and testing are scheduled for september.

WP3.1.4 **ASUs**: *A. Irles (IFIC), A. Thibault (IJCLab), D. Zerwas (IJClab), T. Suejhara (Kyushu)*

T1 the *gluing* of the sensors on the equipped PCB will be done at IFIC;

T2 testing of the ASU will be done at IFIC (tbc)

WP3.1.5 **SLAB:** *A. Gallas (IJClab)*

The mechanical support of the SLABs will be either a carbon fibre cradle or a carbon fibre plate with some holders.

T1 Update of the design for the new ASUs and SLboard

WP3.1.6 **DAQ:** *J. Maalmi (IJClab), J. Jeglot (IJClab), D Breton (IJClab)*

WP3.1.7 **Structure:** *A. Gallas (IJClab)*

WP3.1.8 **Commissioning & Analysis:** *A. Irles (IFIC)*

WP3.1 Applications

WP3.1.1 **LUXE:** *R. Poeschl (IJCLab), A. irles (IFIC), V. Boudry (LLR)*

WP3.1.2 **Lohengrin:** *D. Zerwas (IJCLab)*

WP3.1.1 **EBES:** *T. Suehara (Kyushu)*

T1 Determination of the background

T2 First real data taking in 2024 after preparing proper shielding.

2.3 Organisation

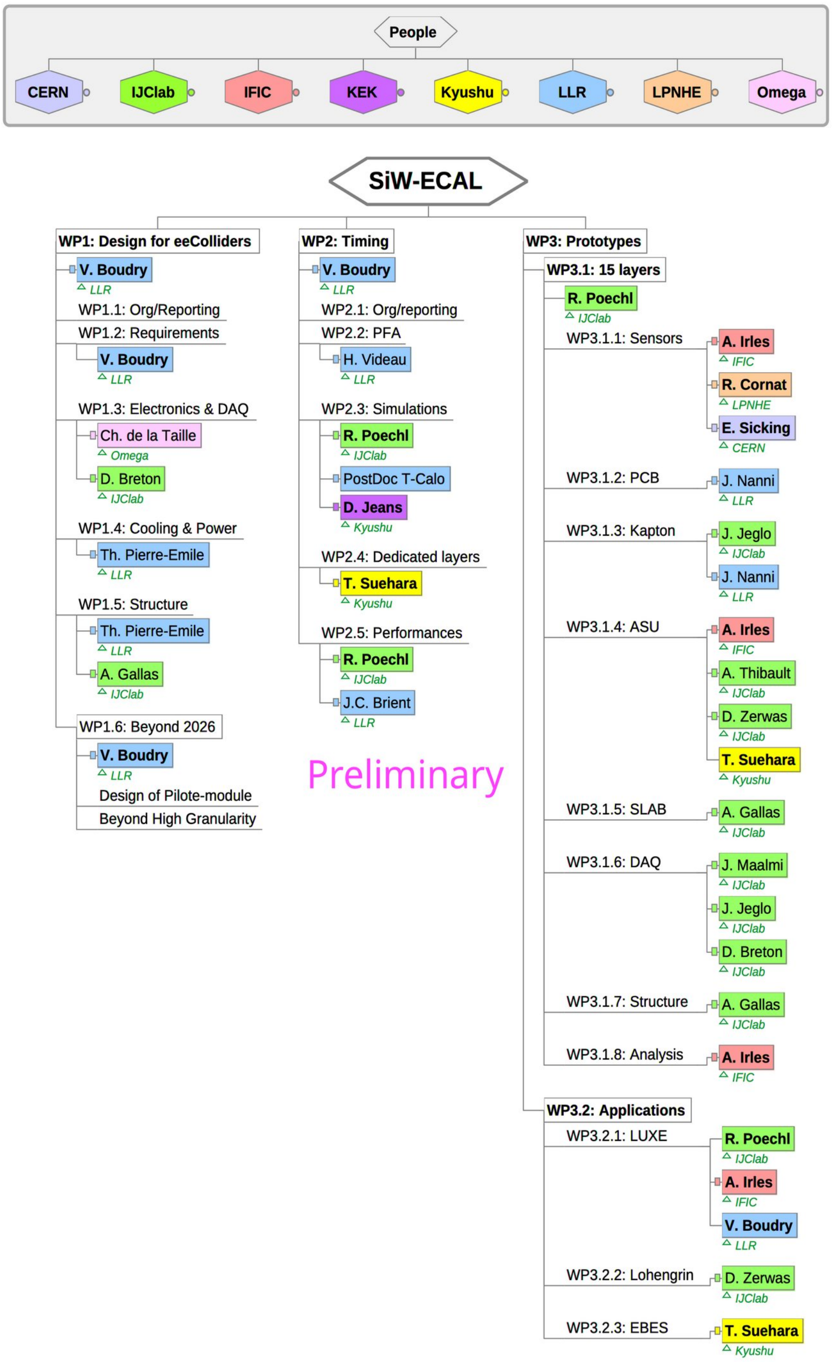
Organigramme simplifié de la collaboration et description du mode de fonctionnement (réunions, reporting interne, suivi des actions, …).

The CALICE collaboration has a standard collaboration structure: regular global physical meetings twice a year, an Institional Board for global policy, a Speaker's Bureau to follow up the analysis, publications and conference contributions, and a Technical Board to follow the detector groups and coordinate the global tools (software, acquisition) and beam test activities.

Detector groups such as the AHCAL or SiW-ECAL have internal meetings about twice a year, and dedicated technical and analysis meetings more or less frequently depending on the current activities.

The CALICE and detector groups frequently present the ideas and advancements to the Detector Concepts collaboration or PED groups for Higgs factories (ILD, FCCee, CEPC).

This structure will evolve in the merging in a DRD collaboration, but is likely to stay similar.



Exemple d'organigramme simplifié

2.4 Analyse des risques du projet

L'analyse de risque est simplifiée pour les projets de R&Ts. Il s'agira de recenser 3 à 5 risques principaux. Leur évaluation sera faite de façon plus sommaire que les canons habituels (voir le référentiel) :

- *Description du risque*
- *Actions en réduction de risque*
- *Responsable d'action*
- *Criticité = Sévérité (impact) x Probabilité (évaluation simplifiée).*
- *Tendance*

Le tableau ci-dessous illustre les risques. Il sera rempli au préalable et maintenu à jour pendant le projet.

Risques	Actions	Responsables actions	Criticité	Tendance
Failure of PCB or Kapton production	Correct design Request new funding	Resp WP3.1	🟡	↘
Lack of manpower for analysis	Recruit PhD's, PD Dispatch efforts	Team Leaders	🟡	→
Health issue of a key person	Redispatch / recruit new talent	Team Leaders	🟢	→
Lack of funding for beam tests	Find new funding sources	Team Leaders	🟡	☐
Mishandling of material	Create new material if funding Run with degraded performances	Resp WP3.1	🟢	↘

Tableau 1: Risques et actions

TEXT HERE

3 Ressources humaines

Les tableaux ci-dessous sont construits au début du projet puis mis à jour au fur et à mesure de l'avancement avec les chiffres extraits de NSIP. Les années à venir sont ensuite mises à jour avec les nouvelles estimations. En cas de forte évolution, une validation devra être obtenue de la direction des laboratoires concernés.

Trois tableaux seront détaillés. Ils seront renseignés dans le fichier Excel associé au projet puis un « copier / coller » sera inclus dans ce document.

- *Tableau 2 : ressources RH « chercheurs » IN2P3 (CR, DR, MC, PR, Doctorants, Post Doc, …)*

- *Tableau 3 : ressources RH « ITA » IN2P3 (IR, IE, AI, T, stagiaires)*
- *Tableau 4 : ressources RH (chercheurs & ITA) des partenaires éventuels.*

Remarque : *les CDD ne figurent pas dans ces tableaux ET dans ceux des ressources financières.*

Le nombre de lignes des tableaux est à ajuster au nombre de chercheurs impliqués. Seront précisés : les prénoms, noms, laboratoire, statut (incluant la source du financement pour les CDD), fraction escomptée du temps en % (la conversion en FTE/ETP se fait automatiquement).

Nom des personnes	Statut	2024	2025	2026	Total (FTE)
LLR		**110 %**	**110 %**	**110 %**	**3,30**
M. Boudry		90 %	90 %	90 %	
M. Brient		10 %	10 %	10 %	
M. Videau		10 %	10 %	10 %	
IJClab		**100 %**	**100 %**	**100 %**	**3,00**
M. Poeschl		70 %	70 %	70 %	
M. Zerwas		30 %	30 %	30 %	
LPNHE		**5 %**	**5 %**	**5 %**	**0,15**
M. Lacour		5 %	5 %	5 %	
Omega		**0,00 %**	**0,00 %**	**0,00 %**	**0,00**
TOTAL (FTE)		**215,00 %**	**215,00 %**	**215,00 %**	**6,45**

Tableau 2: chercheurs et enseignant-chercheurs IN2P3 impliqués dans le projet

Nom des personnes	Statut	2024	2025	2026	Total (FTE)
LLR		**50 %**	**55 %**	**60 %**	**1,65**
M. Nanni		50 %	50 %	50 %	
M. Pierre-Émile		0 %	5 %	10 %	
IJClab		**160 %**	**0 %**	**0 %**	**1,60**
M. Breton		10 %			
Mme Maalmi		20 %			
Mme Thiebault		40 %			
M. Gallas		40 %			
M. Jeglot		50 %			
LPNHE		**5 %**	**0 %**	**0 %**	**0,05**
M. Cornat		5 %			
Omega		**100 %**	**100 %**	**100 %**	**3,00**
M. de la Taille		30 %	30 %	30 %	
M. Thienpont		30 %	30 %	30 %	
M. Dulucq		20 %	20 %	20 %	
M. Raux		20 %	20 %	20 %	
TOTAL (FTE)		**3,15**	**1,55**	**1,60**	**6,30**

Tableau 3: ingénieurs et techniciens IN2P3 impliqués dans le projet

NOTE: Beyond 2024, the IJClab IT ressources will be dedicted to the LUXE activities.

Nom des personnes	Statut	2024	2025	2026	Total (FTE)
IFIC		**130 %**	**130 %**	**130 %**	**3,90**
M. Irles		50 %	50 %	50 %	
M. Márques-Hernández		80 %	80 %	80 %	
Kyushu		**50 %**	**50 %**	**50 %**	**1,50**
M. Suehara		50 %	50 %	50 %	
KEK		**5 %**	**0 %**	**0 %**	**0,05**
M. Jeans		5 %			
CERN		**5 %**	**0 %**	**0 %**	**0,05**
Mme Sicking		5 %			
TOTAL (FTE)		**1,90**	**1,80**	**1,80**	**5,50**

Tableau 4 : personnels autres qu'IN2P3 impliqués dans le projet

4 Ressources financières

Le tableau ci-dessous reprend les demandes (au début du projet) de moyens financiers. Puis chaque année, il est à mettre à jour avec les budgets et dépenses réelles ainsi que leurs évolutions. Les dépenses sont détaillées selon les catégories suivantes :

- *Équipements : détail des principaux équipements et matériels envisagés puis acquis sur le budget du projet.*
- *Fonctionnement : poste des dépenses de fonctionnement des installations et matériels liés au projet*
- *Mission : budget pour les missions du projet (workshops, tests sur site, réunion de collaboration, réunions techniques, …)*
- *RH : aucune ressource pour des CDD, des thèses ou des post-docs ne sont accordées pour le financement des R&T par l'IN2P3 (ces ressources peuvent venir de l'extérieur ou d'autres lignes budgétaires). Des stages (niveau mastère-2 ou en dessous) peuvent être financés de même que de l'assistance technique ou de la sous-traitance de tâche de façon très ponctuelle.*

Les budgets sont exprimés pour l'ensemble de la durée du projet année par année avec le total. Des colonnes seront ajoutées en cas de nécessité. Les montants sont exprimés en €.

Une fiche budgétaire type est à remplir (fichier Excel qui accompagne le dossier). Les tableaux ci-dessous sont alors des « copier / coller » extraits de cette fiche.

Au début du projet et pour les années à venir les colonnes sont des dépenses et des budgets prévisionnels. Lors de la mise à jour de la fiche les dépenses réelles de l'année « N » viennent remplacer les budgets prévisionnels.

		2024	2025	2026	Total
Equipements		**150 000 €**	**210 000 €**	**120 000 €**	**480 000 €**
Casing mechanics		10 000 €			
ASICs Enginering Runs		100 000 €	100 000 €	100 000 €	
PCB production			10 000 €	20 000 €	
DAQ proto and production			20 000 €		
Cooling prototype (if needed)			80 000 €		
Braggs fibre reader		20 000 €			
Silicon Wafers (LUXE)		20 000 €			
Fonctionnement		**2 000 €**	**2 000 €**	**2 000 €**	**6 000 €**
Petits matériels (PC, DAQ)		2 000 €	2 000 €	2 000 €	
Missions		**40 000 €**	**40 000 €**	**40 000 €**	**120 000 €**
Missions		35 000 €	35 000 €	35 000 €	
LIA		5 000 €	5 000 €	5 000 €	
Personnels		**78 000 €**	**78 000 €**	**78 000 €**	**234 000 €**
CDD Instrumentation		75 000 €	75 000 €	75 000 €	
Stages		3 000 €	3 000 €	3 000 €	
TOTAL		**270 000 €**	**330 000 €**	**240 000 €**	**840 000 €**

Tableau 5: ressources financières de l'IN2P3

	Financements	2024	2025	2026	Total
Equipements		**30 000 €**	**- €**	**- €**	**30 000 €**
Silicon sensors	IFIC ?, Kyushu ?	20 000 €			
Kaptons, PCB	AIDAinnova	10 000 €			
Fonctionnement		**- €**	**- €**	**- €**	**- €**
Fonctionnement 2	…				
Missions		**20 000 €**	**20 000 €**	**- €**	**40 000 €**
Missions	Eurolabs	20 000 €			
Missions	DMLabs		20 000 €		
Personnels		**78 000 €**	**75 000 €**	**- €**	**153 000 €**
Post-Doc	ANR T-Calo	75 000 €	75 000 €		
Stages	ANR T-Calo	3 000 €			
TOTAL		**128 000 €**	**95 000 €**	**- €**	**223 000 €**

Tableau 6: ressources financières autres qu'IN2P3

5 Validation des laboratoires participants et visas

Le projet a-t-il été évalué par un Conseil Scientifique de Laboratoire du porteur ?	**~~OUI/~~NON**
Si OUI mettre les principales conclusions de ce CSL en quelques lignes	

Noms des Laboratoires	Noms des Directeurs / Directrices	Visas
LLR	Yves Sirois	
IJClab	Achille Stocchi	
LPNHE	Marco Zito	
Ωmega	Nathalie Seguin-Moreau	

Remarque : Les signatures et visa seront apposés sur la version PDF du document final. La version PDF seule sera envoyée ou déposée sous ATRIUM.

6 Articulation avec les DRD CERN

6.1 Contexte du DRD

Présenter brièvement les objectifs globaux du (ou des) DRD(s) où des contributions en relation avec la FP sont proposées.

The DRD6 is dedicated to the calorimeter R&D. It is in a mounting phase. The SiW_ECAL is closely reated to the DRD theme DRDT 6.2: Highly granular calorimeters with a multidimensional readout for optimised use of particle flow methods; It is the main DRD closely related to this Master Project.

The DRD7 is dedicated to the electronics R&D. Some of its output might find some application in the ASICs and services.

The DRD8 might bring some input to the services (cooling, mechanics), if it is finaly developped (the topics seems to have been integrated into the DRD TA's).

6.2 Description des liens avec les DRD

Indiquer les programmes stratégiques de la feuille de route détecteurs ECFA qui sont concernés par la proposition. Rappeler, si pertinent, les types de détecteurs auxquels la R&T proposée s'applique.

Présenter dans un tableau la correspondance entre les objectifs et le plan de développement exposés dans les sections 1 et 2 et les contributions proposées aux Work Package/délivrables du (ou des) DRDs concernés.

Identifier les opportunités offertes par le(s) DRD(s) pour des contributions souhaitées qui ne sont pas encore couvertes ou viendraient en extension de celles faisant l'objet d'un Master Projet IN2P3 existant.

In the current (but devlopping) organisation, this project is one of the main project in DRD6 Work Area 1 : *Sandwich Calorimeters with fully embedded electronics*.

It is also linked to servral transverse Activities:

- TA *Electronics and Data Acquisition* for the ASICs developments.
- TA *Testbeam infrastructure* for the beam test campaigns
- TA *Detector Physics, Simulation, Algorithms and Software Tool*
- TA *Industrial Connections and Technology Transfer* (connector and preparation industrializeable solutions)
- TA *Mechanics and Integration*

6.3 Organisation

Indiquer, si pertinent, les opportunités de rejoindre d'autres propositions de contributions IN2P3 au(x) DRD(s), et/ou de participation à des collaborations internationales élargies (basées sur un partage d'objectifs, de compétences et de ressources).

The SiW-ECAL prototype activities are already integrated into:

- the CALICE collaboration, which should be superseeded by the DRD6
- the LUXE collaboration, just joined by many groups (IJClab, LLR, IFIC).

The design of a detector and timing studies are closely linked to :

- the ILD collaboration, proposing a detector concept for the ILC and the FCC (probably to be merged with the CLD concept sometime soon)
- FCC, ILC (IDT) and CEPC Physics and Detector (PED) groups
- the DRD6 (for timing, and some TA like mechanics, DAQ, services, …)

6.4 Ressources Humaines

Répartir les RH de la section 3.1 par WP/délivrable DRD. Distinguer (tableau 1) les personnels disponibles contribuant à des activités en cours et (tableau 2) les RH nouvelles considérées.

Si les RH sont identiques pour différents WP/délivrables effectuer un regroupement dans les tableaux. Commenter et motiver brièvement les évolutions attendues dans le temps. Identifier les opportunités de financement partagé au sein la collaboration pour certains WP/délivrables considérés dans la proposition.

Tableau 1 : RH disponibles contribuant à des activités en cours

FTE	2024	2025	2026
WP1	V. Boudry (Ch) 50 %, D. Breton (IR) 10%, Ch. de la Taille (IR) 30%, Thienpont (IR) 30%, Dulucq (IR) 20%, Raux (IR) 20%, Gallas (IR) 5%,		
WP2	V. Boudry (Ch) 20 %, R. Poeschl (ch) 20 %, H. Videau (Ch) 10%, JC Brient (Ch) 10% CDD LLR 100%		
WP3	V. Boudry (ch) 20 %, R. Poeschl (ch) 50 %, D. Lacour(ch) 5 %, R. Cornat (IR) 5 %, J. Nanni (IR) 50 %, J. Maalmi (IR) 20 %, J. Jeglot (IR) 50 %, A. Thibault (IE) 40 %, A. Gallas (IR) 35 %, D. Zerwas (ch) 30 %		
Total	5,35		

Tableau 2 : RH additionnelles considérées

FTE	2024	2025	2026
WP1	Th. Pierre-Emile (IR) 5%	Th. Pierre-Emile (IR) 10%	Th. Pierre-Emile (IR): 15%
WP2			
WP3	CDD IJClab 100 %	CDD IJClab 100 %	

Total	1.05	1.10	1.15

6.5 Ressources financières

Répartir les RF de la section 3.2 par WP/délivrable DRD; limitées aux matériels et équipements, infrastructure et fonctionnement mis à disposition du DRD. Distinguer (tableau 1) les RF disponibles (budget annuel/récurent accordé aux activités existantes) et (tableau 2) les RF additionnelles considérées. Identifier, si pertinent, les couts communs/partagés avec d'autres propositions IN2P3. Commenter et motiver brièvement les évolutions attendues dans le temps. Identifier les opportunités de financement partagé au sein la collaboration pour certains WP/délivrables considérés dans la proposition.

Tableau 4 : RF disponibles (budget annuel/récurent accordé aux activités existantes)

k€	2024	2025	2026
WP1			
WP2			
WP3	40 (mission) 10 (Kaptons/Casing) 2 (Fonc)	40 (mission) 2 (Fonc)	20 (mission) 2 (Fonc)
Total	52	42	22

This budget takes the hypothesis of a minimal support, similar to the one in 2022, to perform the beam test of the 15-layer prototype in 2024 and 2025, and conferences and work session in 2026. Part of the 10k€ for material in 2024 could be taken from the AIDAinnova.

Tableau 5 : RF additionnelles considérées

k€	2024	2025	2026
WP1	100 (ASIC) 20 (Bragg Reader)	100 (ASIC) 80 (cooling proto) 10 (PCB)	100 (ASIC) 20 (PCB)
WP2			
WP3	20 (Wafers)		
Total	140	200	120

7 Bilans des activités

Ce chapitre sera mis à jour année après année. On y décrira le bilan des activités de l'année passée et l'évolution du projet avec ses difficultés, ses risques, ses réussites, …

7.1 Bilan année N

Votre description.

7.2 Bilan année N+1

Votre description.

7.3 Bilan année N+2

Votre description.

8 Conclusions et bilan général

Ce chapitre conclusif sera rédigé à la fin du projet et fera un bilan synthétique de celui-ci. Il pourra aussi introduire des perspectives.

9 Publications

La direction d'institut souhaite promouvoir et augmenter la visibilité de nos développements technologiques. Au moins une publication est requise dans le cadre du projet. Ce chapitre décrit les articles et publications ayant trait au projet, prévues, réalisées ou en cours de réalisation.

<u>Publications prévue</u>

Les décrire brièvement

- The response of the CALICE SiW-ECAL to the low and energy electrons on BT2021 (2024)
- Specifications for timing and cooling (2025-Q2)
- EoI for the FCC (2025-Q3)
- Proposition for a FCC detector (2026-Q4)
- Reference sample for GEANT4 simualtions on BT2024 data (2026)

<u>Publications en cours de réalisation</u>

Les décrire brièvement

- TDR for the LUXE experiment

<u>Publications faites</u>

Mettre les références.

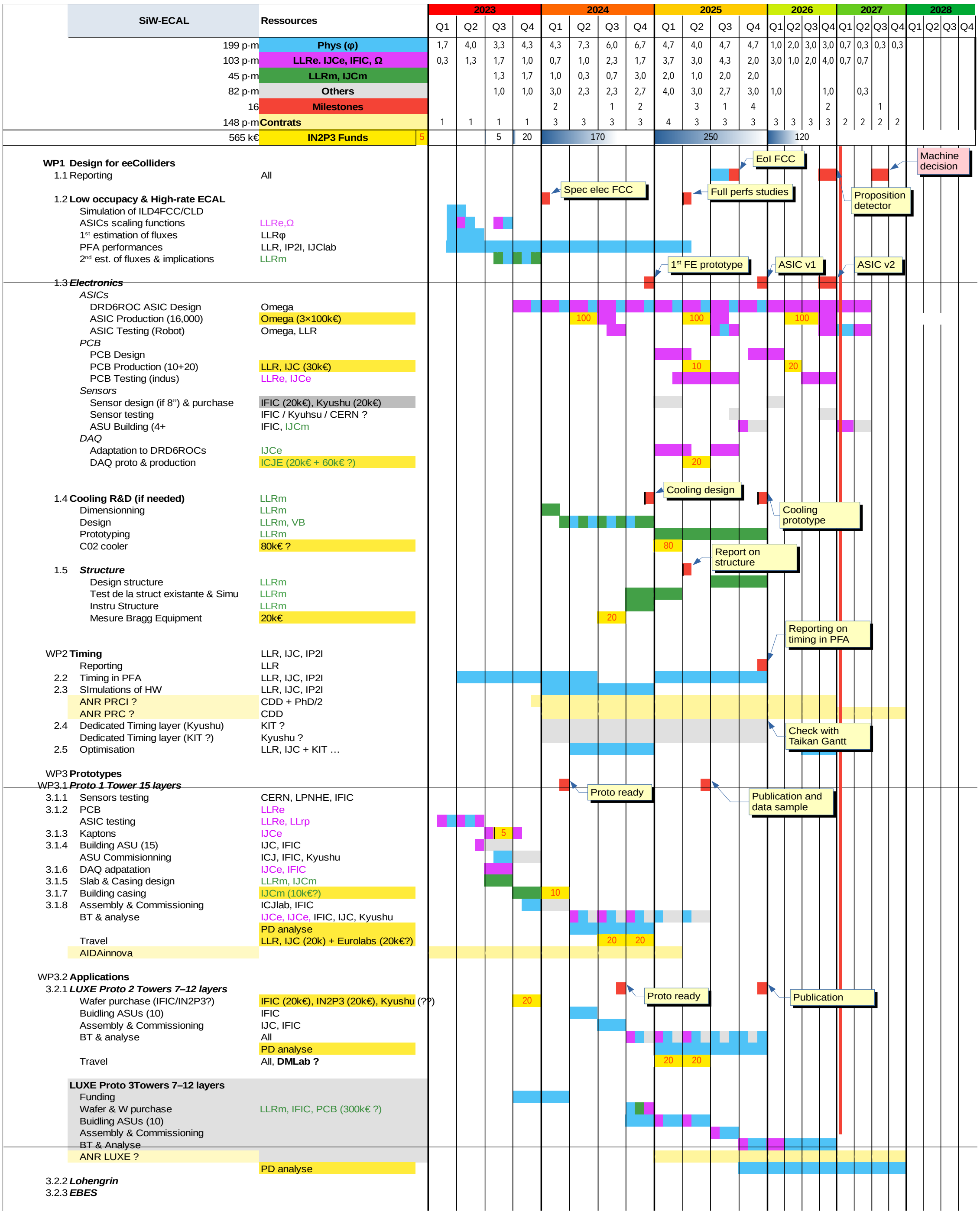
- All CALICE SiW-ECAL publications

- ILD Letter of Intend (LoI), Detector Baseline Description (DBD), ILD: Interim Design Report (IDR)

10 Références

On indiquera ici au fil du projet les références des documents et notes techniques principales ayant été rédigés dans le cadre du projet.

- To be completed.



11 Calendrier du projet avec jalons principaux

Ici sera inséré une image du planning du projet incorporant les principaux jalons et dates d'obtentions de ceux-ci. Ce planning sera mis à jour chaque année en fonction de l'évolution réelle du projet.