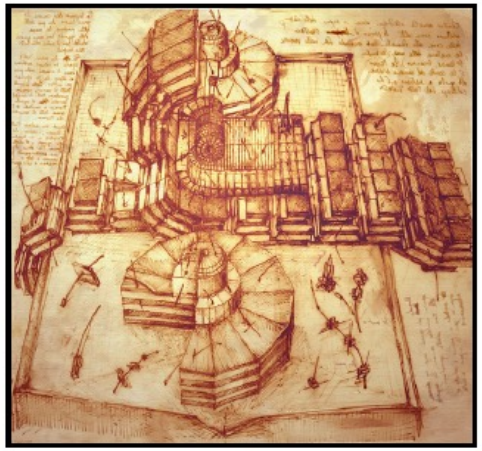
GT08
DETECTORS
&
ASSOCIATED INSTRUMENTATION

MARCH 2019
Sébastien Viret + GT

Du projet au détecteur: résumé



1. Présentation du groupe de travail
2. Objectifs
3. Etat des lieux
4. Prospectives

Prospectives de l'IPNL

vs.

Prospective IP2I 2019

JUNE 2020

Detectors for the Future

2020-2030 French Strategic Plan for Nuclear Physics, Particle Physics, Astroparticle Physics and associated Technologies & Applications.

Report of the GT08 working group:

DETECTORS & ASSOCIATED INSTRUMENTATION

Authors
Jean-Luc Biarrotte (CNRS/IN2P3), Rodolphe Clédassou (CNRS/IN2P3),
Didier Laporte (CNRS/LPNHE), Julien Pancin (GANIL),
Véronique Puill (CNRS/IJCLab), Laurent Serin (CNRS/IJCLab)

OBJECTIFS GT08
Détecteurs et Instrumentation associée

*… , **the mission of IN2P3 detector teams** is to **focus their main effort** on **the design, development and construction of detectors able to address the IN2P3 research programs**, **and on the associated R&D**…*

*The development of a new detector technology follows **quite a long cycle over at least one decade.***

- *generic 'blue-sky' R&D (TRL 1-3)*
- *prototyping phase, where R&D is more focused towards the future detector project requirements (TRL 4-6)*
- *technological demonstrator phase (once the experiment is approved TRL 8)*
- *final production/industrialization phase (TRL 9)*
- *installation and commissioning*

[RECOMMENDATION 1]

It is of paramount importance to anticipate this long development cycle and **maintain a strong detector R&D activity** so as to push the associated technologies beyond state-of-the-art and meet the challenges of future IN2P3 scientific research.

OBJECTIFS GT08
Détecteurs et Instrumentation associée

*… , **the mission of IN2P3 detector teams** is to **focus their main effort** on **the design, development and construction of detectors able to address the IN2P3 research programs**, **and on the associated R&D**…*

*The development of a new detector technology follows **quite a long cycle over at least one decade.***

- *generic 'blue-sky' R&D (TRL 1-3)*
- *prototyping phase, where R&D is more focused towards the future detector project requirements (TRL 4-6)*
- *technological demonstrator phase (once the experiment is approved TRL 8)*
- *final production/industrialization phase (TRL 9)*
- *installation and commissioning*

[RECOMMENDATION 1]

It is of paramount importance to anticipate this long development cycle and **maintain a strong detector R&D activity** so as to push the associated technologies beyond state-of-the-art and meet the challenges of future IN2P3 scientific research.

Remarque préliminaire sur reco 1 générique :
2 impératifs concurrents en ressources (RH, Equipement) et matière grise !

- construire des dispositifs expérimentaux : comment assurer le cycle long TRL 3 à 9 => « Market » Pull
- faire de la R&T+ R&T et R&D de « rupture » => Techno Push

Réponse

- Chiffrer le rapport ETP_IR(R&DT) / IR(Projet) et fixer des objectifs réalistes chiffrés sur ce rapport vs objectifs d'innovation (Reco 2019)
- Pour un institut de recherche quel est le bon ratio ?
- La solution habituelle est la prise de risque individuel des IR dans leur métier en proposant un R&D pour un expérience

OBJECTIFS GT08
Détecteurs et Instrumentation associée

*… , **the mission of IN2P3 detector teams** is to **focus their main effort** on **the design, development and construction of detectors able to address the IN2P3 research programs**, **and on the associated R&D**…*

*The development of a new detector technology follows **quite a long cycle over at least one decade.***

- *generic 'blue-sky' R&D (TRL 1-3)*
- *prototyping phase, where R&D is more focused towards the future detector project requirements (TRL 4-6)*
- *technological demonstrator phase (once the experiment is approved TRL 8)*
- *final production/industrialization phase (TRL 9)*
- *installation and commissioning*

[RECOMMENDATION 1]

It is of paramount importance to anticipate this long development cycle and **maintain a strong detector R&D activity** so as to push the associated technologies beyond state-of-the-art and meet the challenges of future IN2P3 scientific research.

Remarque en préliminaires sur reco générique : 1 et 15
2 impératifs concurrents en ressources (RH, Equipement) et matière grise !

- construire des dispositifs expérimentaux Comment assurer le cycle long TRL 3 à 9 => « Market » Pull
- faire de la R&T+D de « rupture » => Techno Push

Réponse

- Chiffrer le rapport E
- Pour un institut de re
- La seule solution trou

remarque : On dit qu'on fait du « Techno push » pour survivre mais on fait en grande partie du « Market Pull » : Les R&T IN2P3, ANR, les Prémat CNRS etc … essayent de mettre de l'huile dans ce mode de fonctionnement originel…

OBJECTIFS GT08
Détecteurs et Instrumentation associée

*… , **the mission of IN2P3 detector teams** is to **focus their main effort** on **the design, development and construction of detectors able to address the IN2P3 research programs**, **and on the associated R&D**…*

*The development of a new detector technology follows **quite a long cycle over at least one decade.***

- *generic 'blue-sky' R&D (TRL 1-3)*
- *prototyping phase, where R&D is more focused towards the future detector project requirements (TRL 4-6)*
- *technological demonstrator phase (once the experiment is approved TRL 8)*
- *final production/industrialization phase (TRL 9)*
- *installation and commissioning*

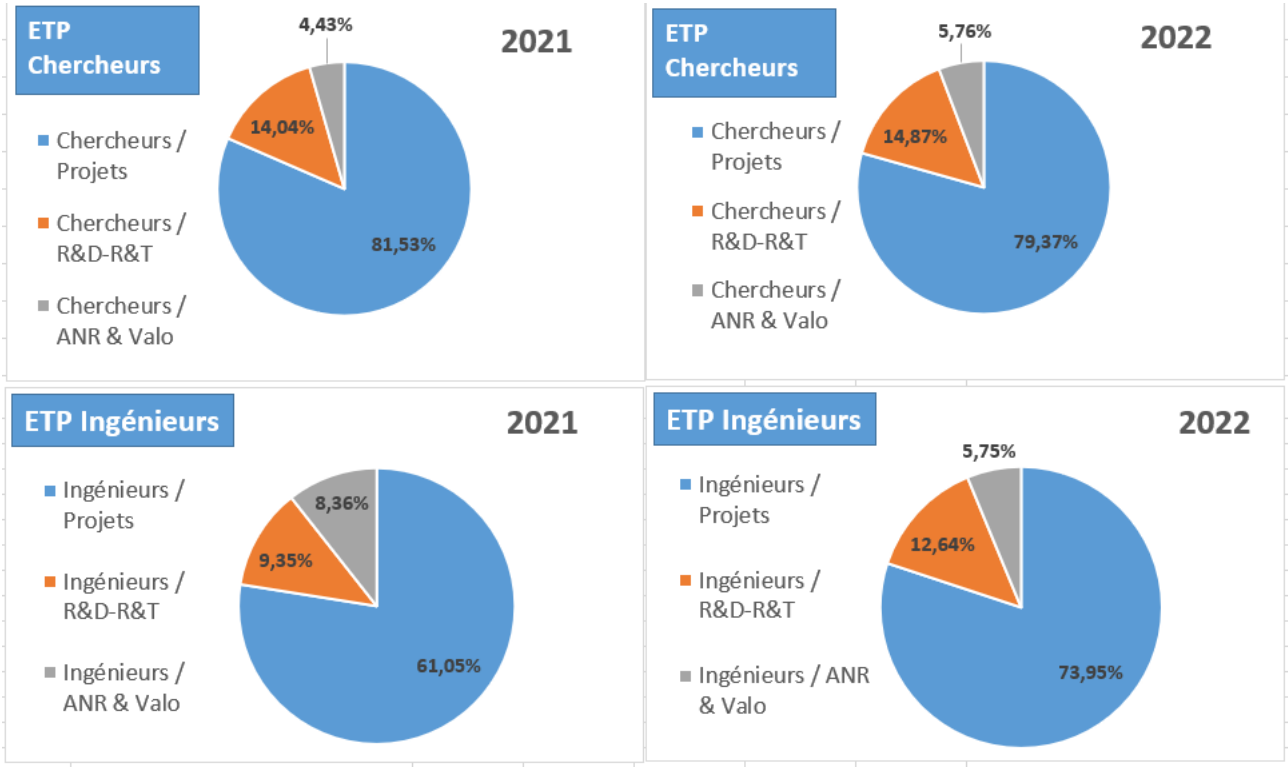
[RECOMMENDATION 15] dans « transverses technologies = métiers IT

-In order to further enhance the existing strike force of IN2P3 laboratories, the different instrumental and technical teams working for the development of detectors – but also accelerators – should **strongly increase their inter-connection and collaboration**, so as to further favor the exchanges of know-how and the emergence of innovative technological ideas.

Remarque :
l'autre moyen est de croire qu'en mettant les gens ensemble on y arrivera mieux … mais avec le même ratio R&D/Projet ...

ETP ratio : Push or Pull ? R&D versus Projet

- Detectors for the future (titre du GT08)
  - ne veut pas dire obligatoirement innovant ?
  - Suivre l'évolution techno est différent d'un nouveau concept
    - Les deux modes ne demande pas les mêmes moyens
    - On pratique plus la veille techno que de l'innovation
- Une techno détecteur innovante c'est au moins 1 M€ … 3-4 ETP …



Lionel C.

GT08 « Science Drivers »

- SD#1 – Push detector development towards enhanced sensitivity and lower background, in particular to detect very rare and/or low signal-to-noise events, like typically for neutrino and gravitational wave detection or for dark matter search.

- SD#2 – Push detector development towards better energy, time and space resolutions, in particular to improve the identification of the particles produced by a collision or a decay event.

- SD#3 – Push detector development towards increased efficiency, reliability and lifetime, in particular when used in extreme conditions like typically in space or in accelerator-based research infrastructures with a harsh radiation environment.

- SD#4 – Push detector development towards high-rate and high-speed read-out with efficient data acquisition, in particular for High-Energy Physics (HEP) and nuclear physics experiments.

Découpage du rapport du GT en domaine de détecteurs = domaine de physique + technos

- Semi-conductors (pixels), cryogenics, photo-detectteurs, calorimeters, OG, gaseous, ….
- Le technologies transverses = métiers = méca BE, électroniques, DAQ, Soft

Techno Detectors / Science drivers	Detectors						Transverses Technologies		
	Semi-conducteurs Pixels	Gaseous Detectors	Cryogenic Detectors	Photo Detectors	Calorimeters	Gravitational Wave Detectors	mechanics & cooling	microelectronics	acquisition systems
SD1 sensitivity and lower background => OG, neutrino, DM, DE	Reco 3 Skipper CCD Reco 4 IR/VIS Coord.	Reco 5 min. R&D Reco 6 Ioniz. + light	Reco 7 Bolo	Reco 8 MCP-PMT SiPM		Reco 13 Low-loss Mirrors Reco 14 f-Squeezd	Reco 16 Multi-physics tools CAD Reco 17 3D AF	Reco 18 Techno watch IP block	Reco 19 Clouds Comput. Reco 20 IA, ML sur FPGA
SD2 energy, time and space resolutions => Colliders, Particle decay : PID	Reco 2 MAPS / DeMAPS ps stitching	Reco 5 min. R&D	Reco 7 Bolo array + KIDs	Reco 8 MCP-PMT SiPM Reco 9 Cherenkov	Reco 10 High gran. TPC Li Ar Reco 11 ps Timing Reco 12 PICMIC				
SD3 efficiency, reliability and lifetime, radiation hardness => Colliders	Reco 2 DeMAPS hybrid FCC-hh	Reco 5 min. R&D		Reco 8 Scint. Liquido Li-based elpasolite					
SD4 high-rate and high-speed read-out with efficient data acquisition, => Colliders, Nuclear Physics	Reco 3 hybrid FCC-hh						@ IP2I		

SEMICONDUCTORS (= PIXELS)

Examples of future application in HEP :
VTX Belle II,
ALICE ITS, ILC,
FCCee,
FCChh,..

[RECOMMENDATION 2] **MAPS / deMAPS / Hybrid**

With a well established 5-year program, the promising R&D on MAPS & DeMAPS detectors **should be strongly supported by IN2P3**, while still **keeping the current expertise on hybrid detectors**.

[RECOMMENDATION 3] **Skipper CCD**

Considering the existing expertise at IN2P3, acquired for instance in LSST (IP2I, IJCLab, LPNHE…), a R&D program on skipper CCDs could have a visible impact if a large enough team is identified.

[RECOMMENDATION 4] **EUCLID / LSST**

A better national coordination between the different existing infrastructures addressing IR/visible/UV detectors characterization is strongly recommended.

« Precise timing measurement using these detectors is a new R&D path in which IN2P3 should be involved for its future collider experiments (it is already the case with some ASIC development). »

SEMICONDUCTORS (= PIXELS)

Examples of future application in HEP :
VTX Belle II,
ALICE ITS, ILC,
FCCee,
FCChh,..

[RECOMMENDATION 2] **MAPS / deMAPS / Hybrid**

With a well established 5-year program, the promising R&D on MAPS & DeMAPS detectors **should be strongly supported by IN2P3**, while still **keeping the current expertise on hybrid detectors**.

Digital on Top : comment on le strucutre ?
- en méthode , RH, métiers
- projet : DICE MAPS, PICMIC , TDC, timing, …

could have a visible impact if a large enough team is identified.

[RECOMMENDATION 4] **EUCLID / LSST**

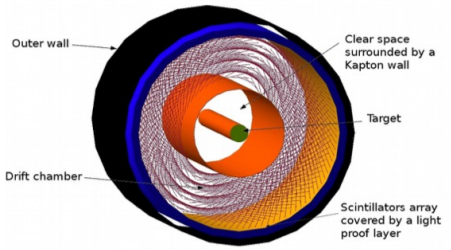
A better national coordination between the different existing infrastructures addressing IR/visible/UV detectors characterization is strongly recommended.

En attente d'un projet spatial … pas de collaborations évidente sur plateforme multi-labo …

« Precise timing measurement using these detectors is a new R&D path in which IN2P3 should be involved for its future collider experiments (it is already the case with some ASIC development). »

GAZEOUS

ALERT



[RECOMMENDATION 5] **Micro Pattern Gaseous Detectors (MPGD: micromegas, GEM and derivatives)**

- The pursuit **of a <u>minimum R&D effort</u>** is essential to ensure the long-term sustainability of **'small-scale' gaseous detectors** and of the associated skills at IN2P3.

[RECOMMENDATION 6] **SCALP LPC Caen**

- The detection concept coupling the ionization signal and the photo-detection of the emitted light is very promising for the forthcoming years and should be further explored.

Veille techno et conservation des compétences …

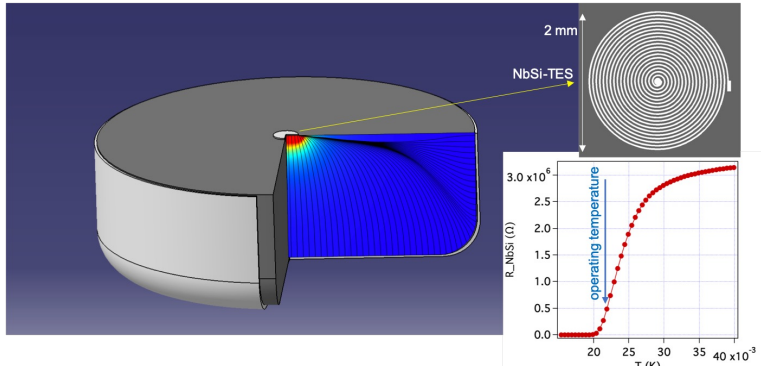
CRYOGENICS DETECTORS

[RECOMMENDATION 7] **CUPID, EDELWEISS, Ricochet, QUBIC, NIKA2, KISS, CONCERTO, PACS, X-IFU Athena, LiteBird, S4, SPICA ...).**

- IN2P3 teams and their main French partners are developing very diverse and innovative R&D projects in the field of cryogenic detection, in particular for mm/sub-mm detection. These activities should be **strongly supported in the long term** to address the needs of future astroparticle and cosmology experiments, **but should better focus on the most promising and priority developments.**

- Plateau Technique cryo @ IP2I évolution au dela de Ricochet ?
- Les Techno dites « Quantiques » , SSED, TES ,KIDs : comment investir ce champ pour le meV-eV DM ?
- Comment ne pas rater le train Qunatum Information Science (QIS) ?
- Que signifie miser sur la plus prometteuse ? Si on observe un excès on voudra voir avec les autres techno ?

CRYOSEL ANR Jules



TES SSED

PHOTO-DETECTORS

the Photomultipliers PMT, Micro Channel Plate PMT (MCP-PMT) and the Silicon Photomultiplier (SiPM)

[RECOMMENDATION 8] Li-based elpasolite scintillators (IJCLab), LiquidO project (CENBG, CPPM, IJCLab, SUBATECH)

- It is highly recommended to pursue the on-going R&D efforts in the scintillator field, in particular on Li-Elpasolite and opaque scintillators which are very promising.

[RECOMMENDATION 9] IJCLab LHC, LHCb (IJCLab, LLR), STCF Physics Beyong Collider (PBC)

- The pursue of the on-going R&D efforts in the Cherenkov detection field should be strongly supported.

le GT est très SiPM …

- Pourquoi on ne passe pas sur du SPAD en techno CMOS ? (Rad Hard ?)

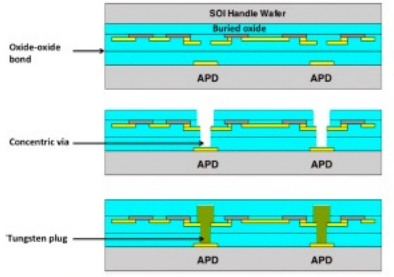


Figure 4. Steps in the Lincoln 3D-integration process to integrate the APD wafer (tier 1) with the first SOI CMOS wafer (tier 2).

3D TSV + GMAPD

2016 MIT Lincon Lab

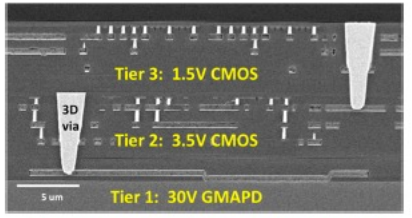
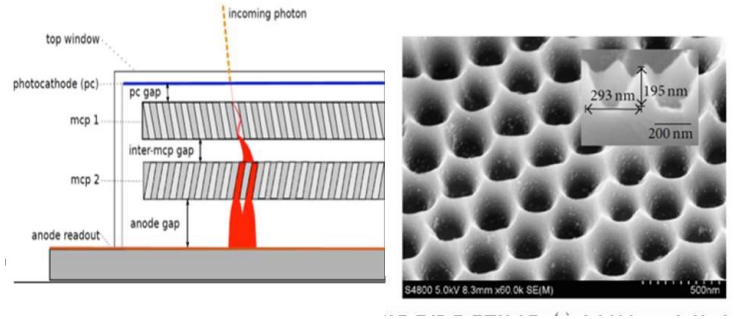


Figure 5. Cross-sectional SEM through a pixel of the 64×64 GMAPD array.

CALORIMETERS

PICMIC



[RECOMMENDATION 10] Dune TPC Lar @ IP2I

- Considering the large expertise of IN2P3 teams, starting a R&D on **high granularity Liquid Argon calorimeters** for future colliders experiments would ***ensure a good use of the Institute technical skills***, providing a very high visibility to IN2P3..

[RECOMMENDATION 11] Electronics et eDAQ @ IP2I : R&T TDC, TDC PICOTI sur FPGA, DICE?, MichRAU

- Precise timing measurement looks to be one of the new features considered for the next generation of detectors. It is therefore crucial for IN2P3 to be involved in these developments.

[RECOMMENDATION 12] PICMIC @ IP2I. : POC TRL3

- IN2P3 should strongly encourage the emergence of innovative and promising developments likely to lead to technological breakthroughs, and therefore **support the development of the PICMIC concept.**

GRAVITATIONAL WAVE DETECTORS

[RECOMMENDATION 13] **LMA**

- It is strategically crucial that the R&D program on low-loss mirrors is strongly supported in the next years so that LMA can keep its world leadership in the domain of high performance large optics.

[RECOMMENDATION 14]

- The on-going R&D activities on in-vacuum squeezed sources should be strongly supported.

R&D du LMA – Positionnement sur instrumentation et detector sur ET ?
Instrumentation autre que Mirroir ?

TRANSVERSES mechanics & cooling

[RECOMMENDATION 16]

- Multi-physics simulation platforms, including CAD tools, are vital to ensure a proper detector design, in particular to overcome the emerging cooling issues. These tools are also more and more complex and it is essential to secure and further develop, in a coordinated way through specific training and enhanced inter-laboratory exchanges, the expertise already existing in IN2P3 teams.

???? On a des choses

[RECOMMENDATION 17]

- It is essential to define within the next years a proper strategy on how to precisely develop the **Additive Fabrication technology** in our laboratories (fully in-house, in partnership with industry, or mainly through outsourcing).

Scintillation 3D Additive Fabrication

initiative CERN (Muodim R&T : Emilie)

Calo (new MP IN2P3 ? Susanne)

TRANSVERSES microelectronics

[RECOMMENDATION 18]

- Technology watch on micro-electronics should be enhanced. In particular, some IP blocks should be produced with the emerging technologies (e.g. 28 nm) so as to learn and qualify them and identify a suited technological roadmap for the next 10 years.

- Pourquoi bloc IP 28nm est la seule reco ?
- Digital on Top ? ML in ASICs ? - Timing ? Stitching - Electronics 3D TSV …

Q : Pour l'IP2I le timing est-il une opportunité pour se démarquer ?

Q : Comment développer le Digital on Top ?

« Precise timing measurement using these detectors is a new R&D path in which IN2P3 should be involved for its future collider experiments (it is already the case with some ASIC development). »

TRANSVERSES acquisition systems

[RECOMMENDATION 19] eDAQ + Calcul embarqué SoC

- IN2P3 teams are currently studying the feasibility of implementing **neural networks inside FPGAs. This Artificial Intelligence approach** is extremely promising and **should be strongly pursued.**

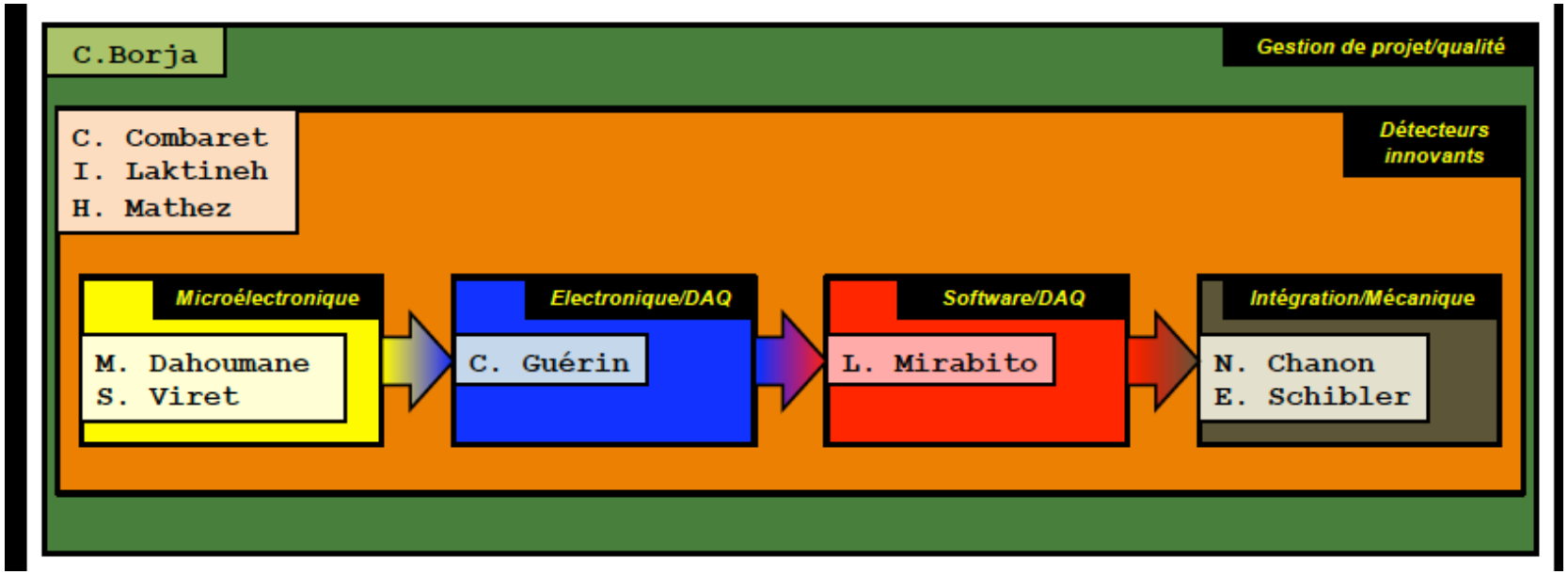
[RECOMMENDATION 20] IoT , Timing - WR ?

- The acquisition frameworks that meet the online constraints of IN2P3 experiments have a very strong distributed component and the development of **computing clouds could allow the optimization of online scientific computing replacing advantageously the grid approach**.

Relier à GT09 dans la présentation de Giens :
Il y a quand même une spécificité sur l'embarqué qui n'est pas clairement apparu dans GT09
Présentation Olivier

L’approche Prospectives 2019 par la chaine de détection

il faut la poursuivre dans se sens même si on est « orthogonal » au Reco GT08 dans la forme mais pas sur le fond ?
=> discussion



Si oui , Comment ?

Les plus motivés & libres (min 30%/agent) en

+ Calcul GPU Algorithm
+ IoT
+ DAQ
+ Techno/ Science Case

Timing + IoT + ML + IA sur chaine de détection + **calibration + perfos** : peut être notre valeur ajoutée IP2I

Le Covid a arrêté le process à l ’étape 2 (slide suivant) faut-il reprendre le processus par un science case ?

1. Présentation du groupe de travail
2. Objectifs
3. Etat des lieux
4. Prospectives

→ Mandat du groupe de travail

- **Intitulé:** GT autour des détecteurs futurs, les outils de conception, intégration, DAQ et électronique, et la qualité.
- **Objectif:** faire un bilan de nos compétences dans ces domaines, décrire les enjeux et évolutions futurs, comment inscrire nos projets dans ces évolutions?
- **Travail à réaliser:** élaboration d'un rapport au premier semestre 2019.

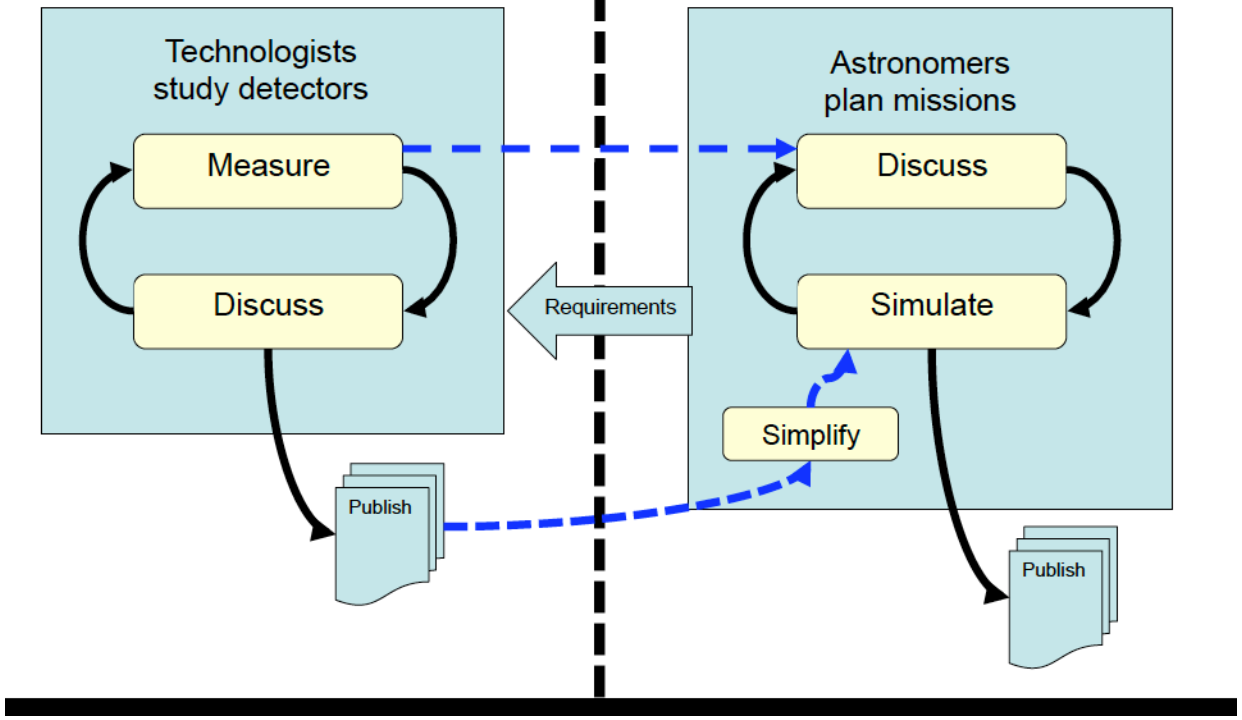
→ Fonctionnement du groupe de travail

- **Etape 1:** bilan de compétence par les différents sous-groupes, ébauche d'une réflexion sur les évolutions
- **Etape 2:** mise en commun. Mise en avant des synergies possibles, des opportunités les plus prometteuses et réalistes.
- **Etape 3:** première version d'un document de synthèse donnant des recommandations sur les orientations à venir. Discussion au sein du GT
- **Etape 4:** présentation du rapport aux membres du laboratoire impliqués.

STOP HERE

2012 Caltech : Roger Smith et Jason Rhodes

Previous culture, friendly collaboration but somewhat separate



Why practice in the lab? …in mission definition phase.

- End to end test of real hardware is makes proposal more credible.
  - Numerical simulations are most useful for testing sensitivities,
  - Are we asking the right questions?
- Verify accuracy / precision limits.
- Develop/test mission requirements.
  - pointing, PSF quality/uniformity, image scale, thermal stability, etc
- Test how well calibration methods work. New ideas?
- Improve TRL: detectors, electronics, algorithms.

Aujourd'hui 2022 on appelle cela du Digital Twin

Niveau de maturité techno : TRL

TRL / Niveau de Maturité technologique
1. Principes de base observés et rapportés
2. Concepts ou applications de la technologie formulés
3. Fonction critique analysée et expérimentée ou preuve caractéristique du concept
4. Validation en laboratoire du composant ou de l'artefact produit
5. Validation dans un environnement significatif du composant ou de l'artefact produit
6. Démonstration du modèle système / sous-système ou du prototype dans un environnement significatif
7. Démonstration du système prototype en environnement opérationnel
8. Système réel complet qualifié à travers des tests et des démonstrations
9. Système réel prouvé à travers des opérations / missions réussies