ALLEGRO Concept-Detector

F. Djama (CPPM Marseille)

Many thanks to N. Morange (IJCLab) and G. Marchiori (APC)

History of ALLEGRO

- **FCC-hh**
  - 2015 – 2019 : first ideas to adapt Noble Liquid calorimeter technique to FCC-hh for ECAL
  - 2019: CDR, input to the 2020 ESPPU
  - 2022: Part of the FCC-hh reference detector

- **FCC-ee**
  - 2021: Adapt to FCC-ee
  - 2024: Noble Liquid calorimetry in WP 2 of the DRD 6 Collaboration

- **Concept Detector**
  - 2022: proposed Concept Detector centered on Noble Liquid electromagnetic calorimetry.
  - Scintillator/Fe HCAL joined (from FCC-hh)
  - Other subdetectors : based on IDEA concept. Included in FCC software.
  - But open to proposals
  - 2023: Found a name: **A Lepton-Lepton collider Experiment with Granular Read-Out (ALLEGRO)**
  - 2024: kick-off meeting

- **2025:**
  - Continue hardware and software efforts for ECAL (and HCAL) calorimetry : **talks from Zhi-Bo and Giovanni**
  - Many sub-detector proposals in discussion
  - Expression of Interest submitted to ESPPU 2026
  - Web page : https://allegro.web.cern.ch/

Expression of Interest

- <u>Submitted to 2026 ESPPU</u>

- 170 authors from 47 institutes

- ~ 30 authors from 9 French Laboratories

- French laboratories:
    - APC, CPPM, IJCLab, IP2I, IPHC, IRFU, LAPP, LPNHE, OMEGA

- French contributions:
    - Vertex detector/MDI
    - Tracker
    - Timing layer
    - ECAL
    - Software

- LPSC recently joined the ECAL

- As you know, all groups were part of many other submissions to 2026 ESPPU concerning various sub-detector R&D.

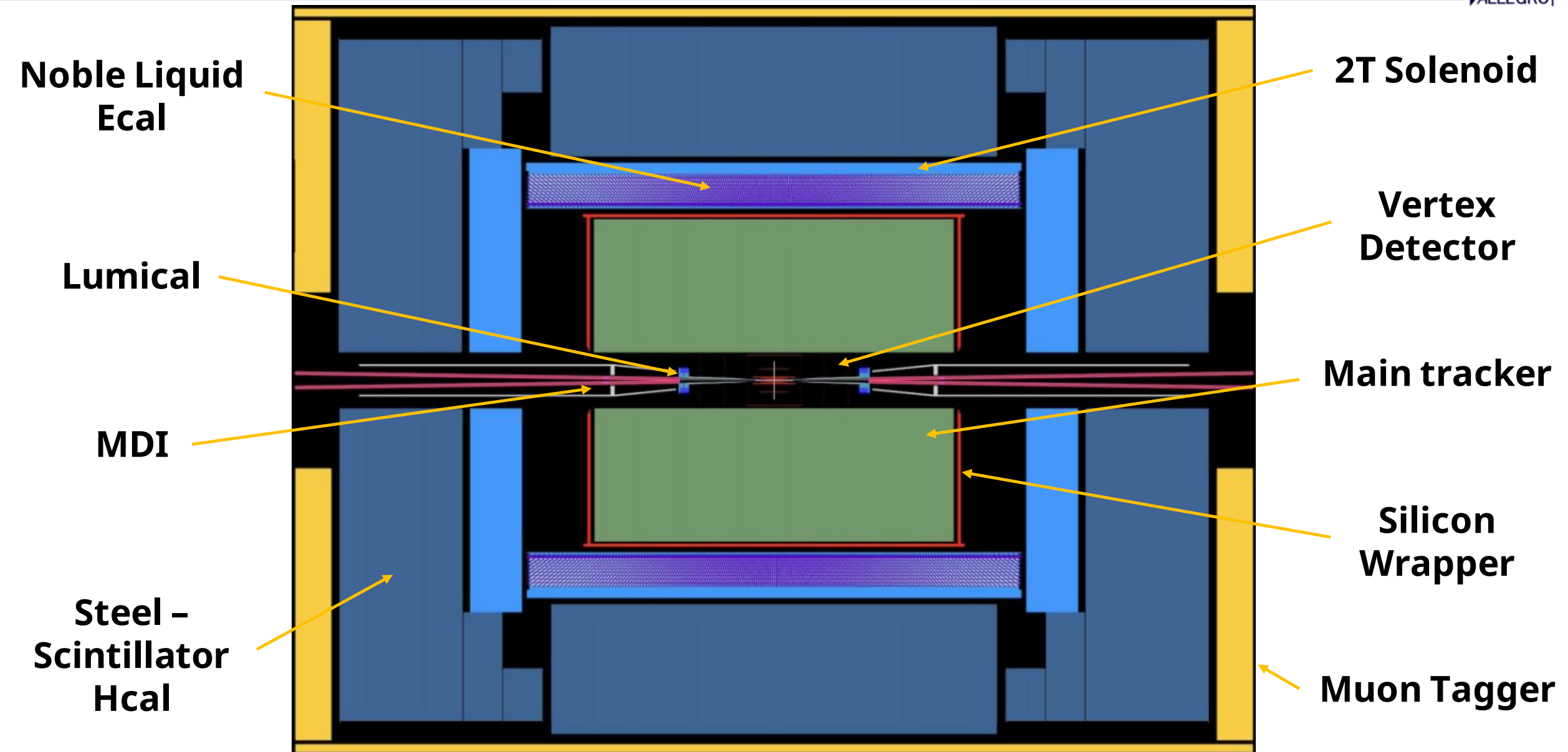## Expression of Interest for the ALLEGRO Full-Detector Concept for FCC-ee

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The Next Few Years…

- The **youngest** FCC-ee concept detector…

- We aim to propose ALLEGRO as a high-performance general-purpose detector concept.

- Technology choices concerning sub-detectors other than ECAL are **fully open**.

- In the coming years there could be **several options** for the different ALLEGRO sub-detectors. They should be integrated in **FCC-ee software** to be evaluated and compared. **Key4hep** is built on such ideas.

- Selection of base-line options after FCC-ee decision, before entering CDR and TDR steps.

- The community is being organized.
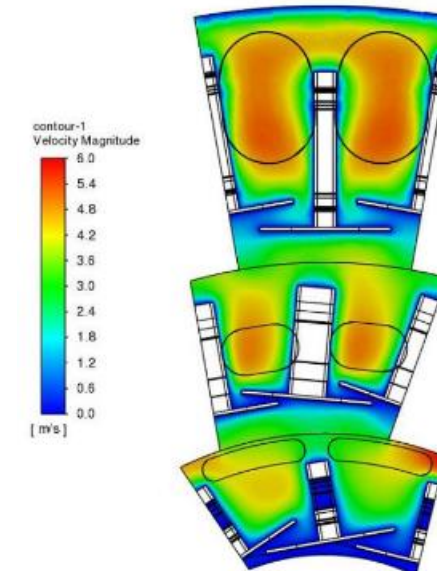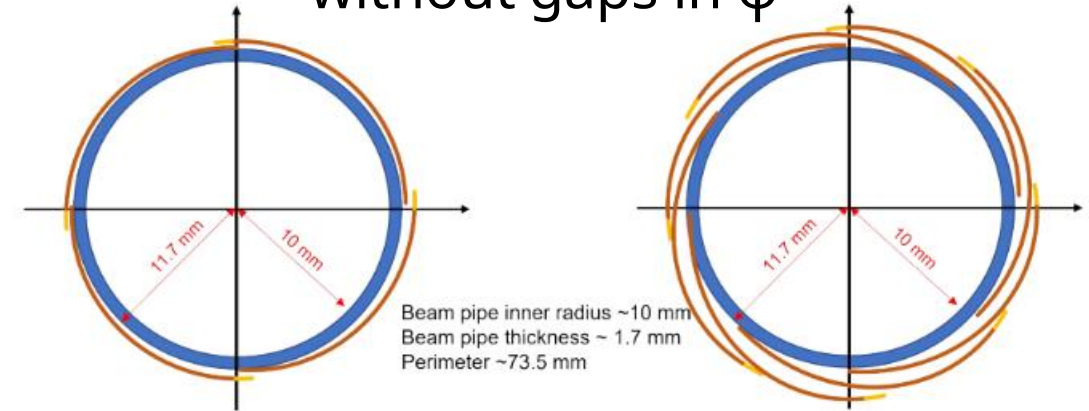
The ALLEGRO Detector Concept

Noble Liquid Ecal

2T Solenoid

Lumical

Vertex Detector

MDI

Main tracker

Steel – Scintillator Hcal

Silicon Wrapper

Muon Tagger

Vertex Detector

FCC Seed: curved sensors without gaps in φ

- **Several group interested with different technologies and layouts.**
  - SEED layout is one of them

- **Several CMOS processes available**
  - e.g TPSCo 65nm

- **Spatial hit resolution**
  - 3μm per layer achievable with 15μm pitch or 25μm pitch with charge sharing

- **Cooling**
  - Study air-flow cooling to minimize X_0
  - Studied for IDEA Vertex Detector so far

Beam pipe inner radius ~10 mm
Beam pipe thickness ~ 1.7 mm
Perimeter ~73.5 mm

11.7 mm   10 mm

contour-1
Velocity Magnitude
6.0
5.4
4.8
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0.0
[m/s]

Straw Trackers Studies

Recent proposal as alternative to Drift Chamber

- Drift Chamber is still a valid opion to ALLEGRO
- Potential advantages of a straw tracker:
  - Comparable resolution with greater design flexibility, PID
  - Operational robustness (broken wires)
  - Economical

- Many straw trackers built for recent experiments
  - GlueX, NA62, PANDA, Mu2e, DUNE ND…

- Interesting R&D paths
  - Overall detector design
  - Single tube production and assembly (minimize X_0)
  - Gas studies, electronics for dN/dx measurements

N_{straws}	R_{straw} [mm]	Material [X_0]	$\frac{\sigma_p}{p}$
100	9.7	1.3%	$0.52\% \oplus 0.15\% = 0.54\%$
112	8.7	1.5%	$0.49\% \oplus 0.16\% = 0.52\%$
200	4.9	2.5%	$0.36\% \oplus 0.21\% = 0.42\%$

$\Rightarrow$ Straw-tracker alternative fully competitive with the drift-chamber.
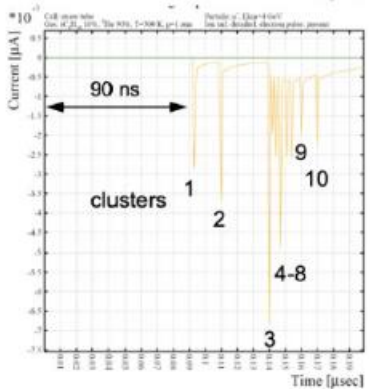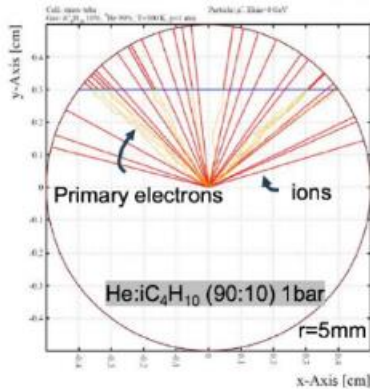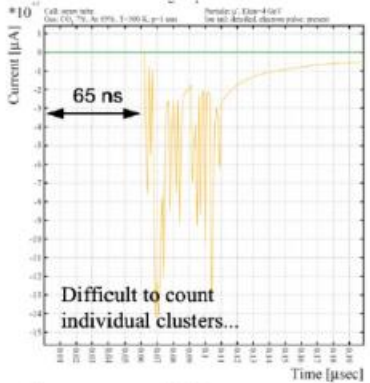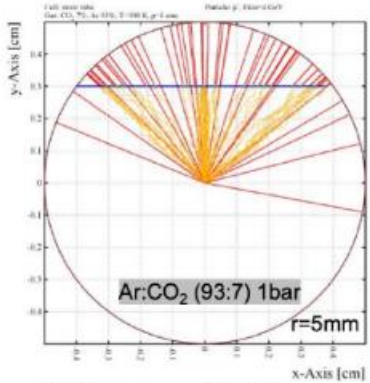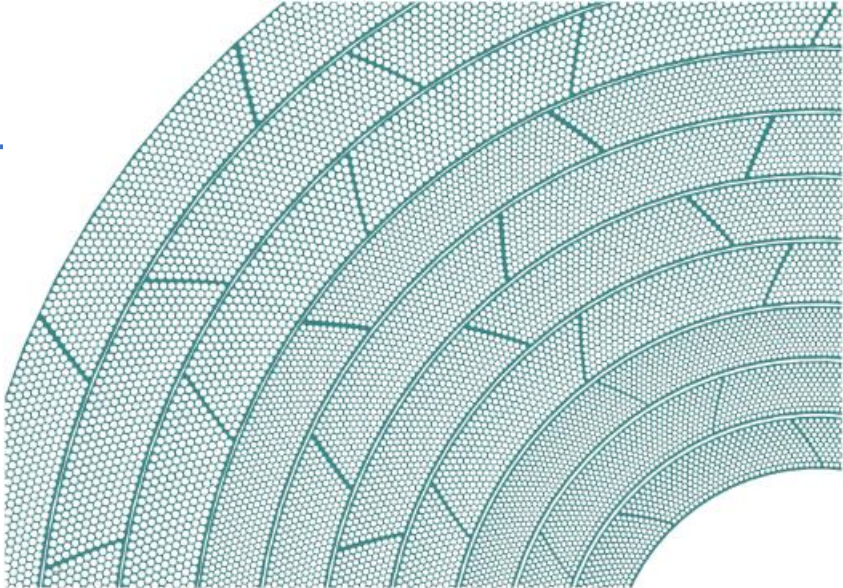
Silicon Wrapper

Add last precise tracking layer in front of calorimeter

- ## Two main goals
  - Last measurement point 'anchors' gaseous tracker and significantly **improve high-pT resolution**
  - **Precise timing:** provide ToF to complement dN/dx measurement for **PID**
  - aka: 4-D tracking

- ## Several technologies proposed
  - DMAPS, LGAD, AC-LGAD, LGAD-RSD
  - All aim few **10ps / layer**
 - Design will learn from HL-LHC detectors

MAPS-LGAD


IDEA tracker resolution σ_{pt}/pt
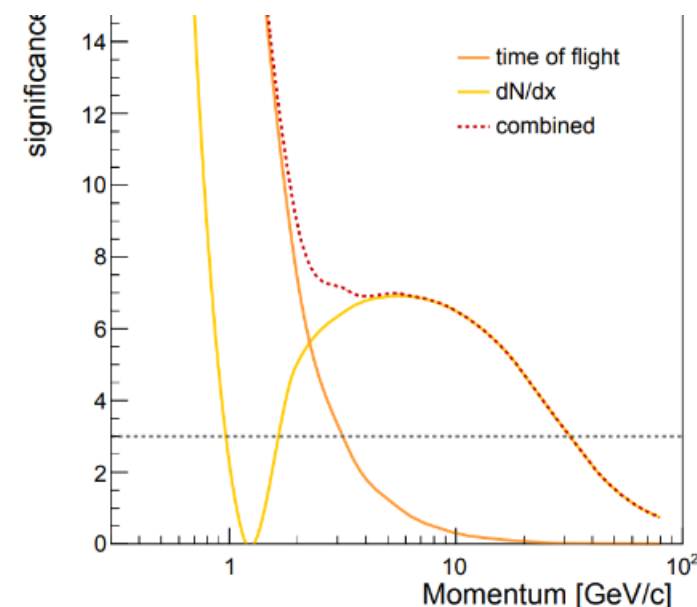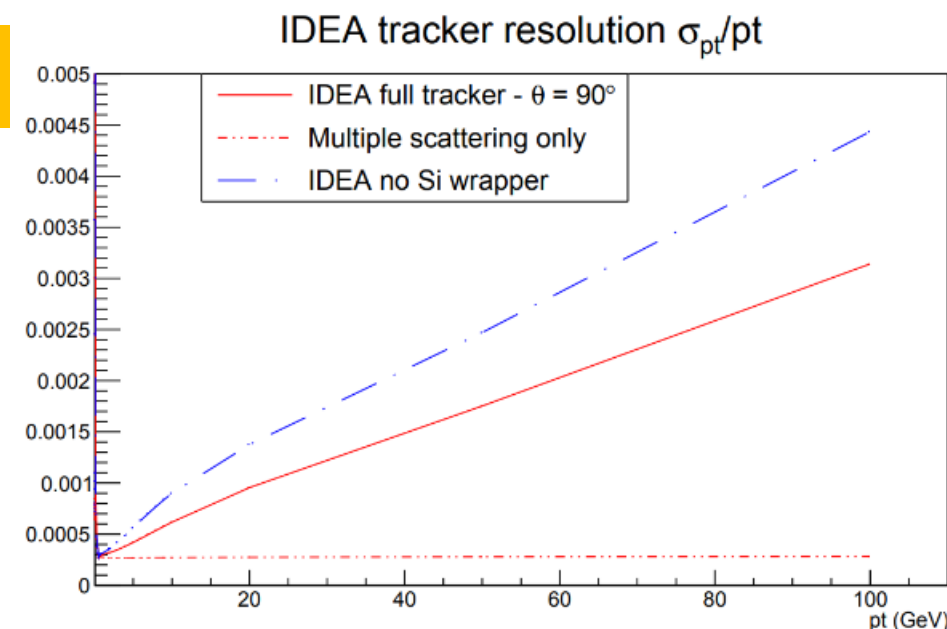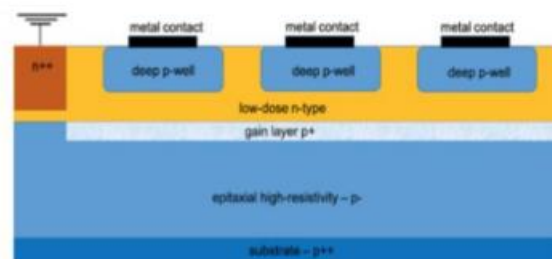
Scintillating Tiles Hcal

- HCal inspired by ATLAS TileCal implemented in FCC Fullsim
  - Either with WLS (à la ATLAS), or with SiPM on Tiles (à la AHCAL)
  - Serves as return yoke

- Design
  - 5mm **steel absorber** plates alternating with 3mm **Scintillating tiles**: 8 - 9.5λ
  - 128 modules in φ, 2 tiles/module, 13 radial layers
  - Optimisation of segmentation and reconstruction

- Prototype studies starting

- Performance
  - Ecal + Hcal combined clustering implemented
  - **Single-pion resolution: 35%/√E**
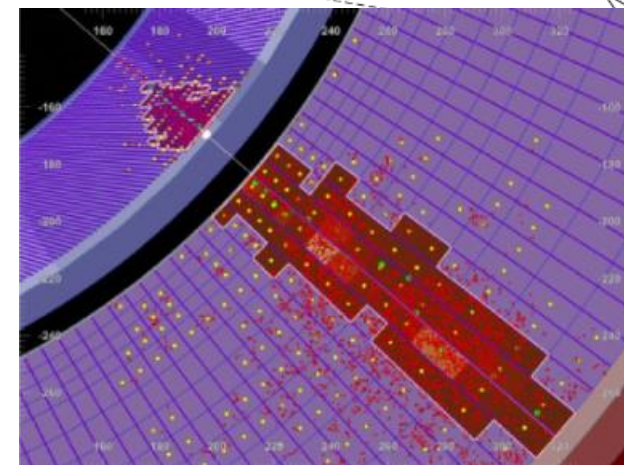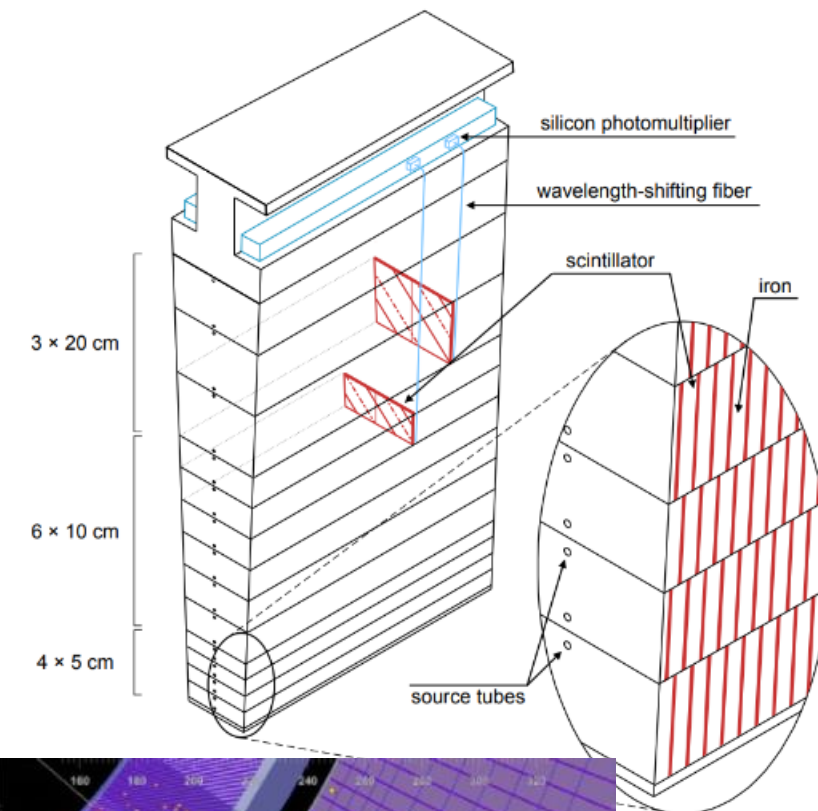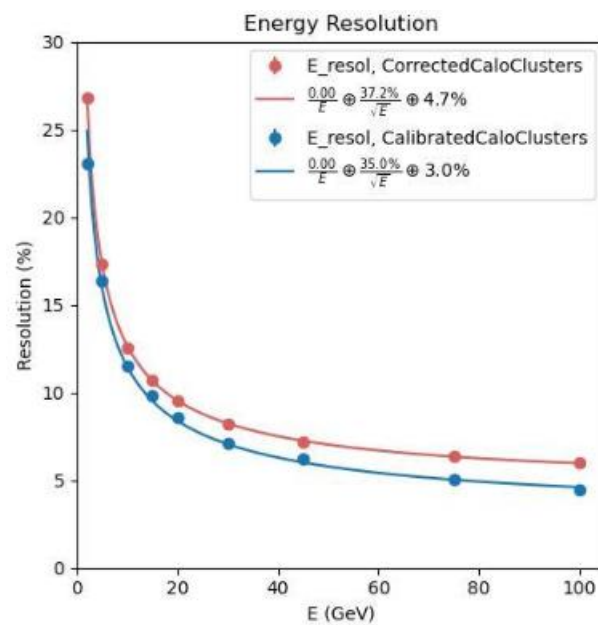
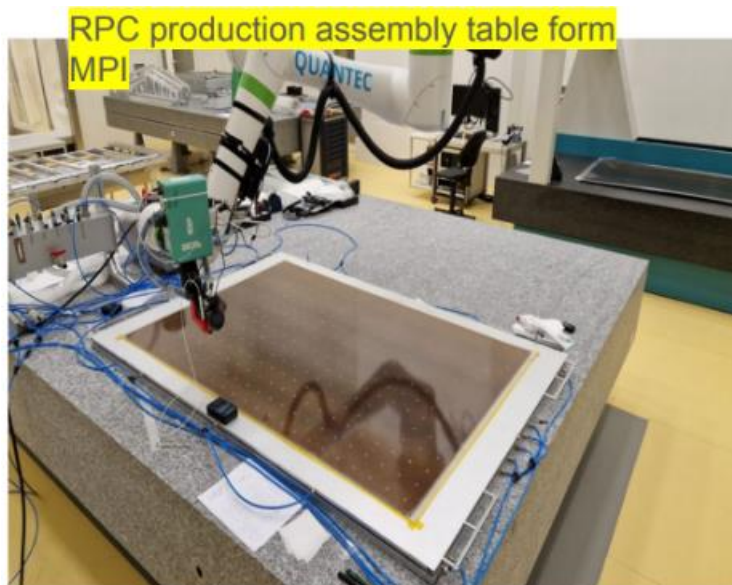# Muon Tagger

- Hcal acting as return yoke ⇒ very little B-field in muon system
  - Simple muon tagger, no spectrometer

- Many technologies proposed
  - RPCs, MDT, MicroMegas, scintillators

- Time-of-flight capabilities might be an advantage
 - Esp. for exotic searches (LLP)
 - Need more studies to make the case

Lumical
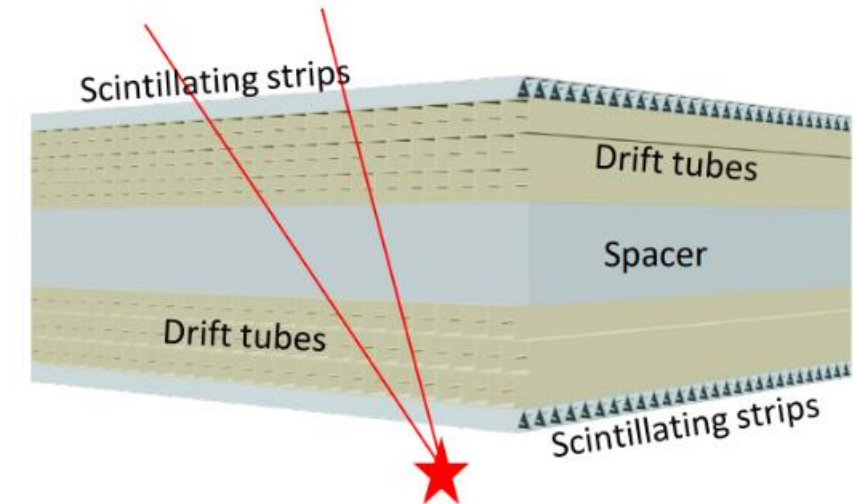
Goal: luminosity measurement at 10^{-4} !

- ## Challenging requirements
  - Position and acceptance exquisitely well known (~10μm level)
  - Fast response
  - High granularity (count Bhabhas)

- ## Implementation concepts
  - **Compact sandwich SiW calorimeter**
    - 25 layers of 3.5mm W (1 X_0 each)
    - 26000 channels

  - **Quantum sensors (SNSPD)**
    - Innovative solution based on superconducting nanowire detectors
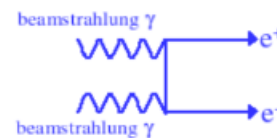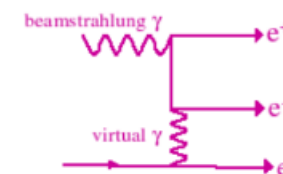   - Feasibility to be assessed

TDAQ
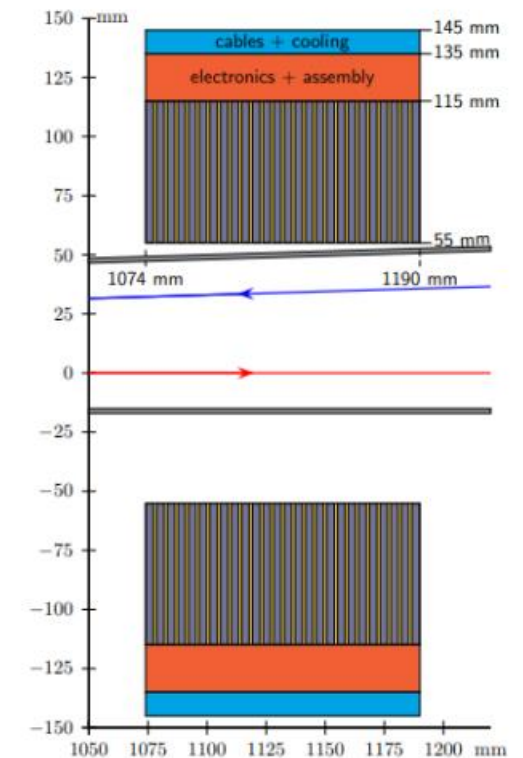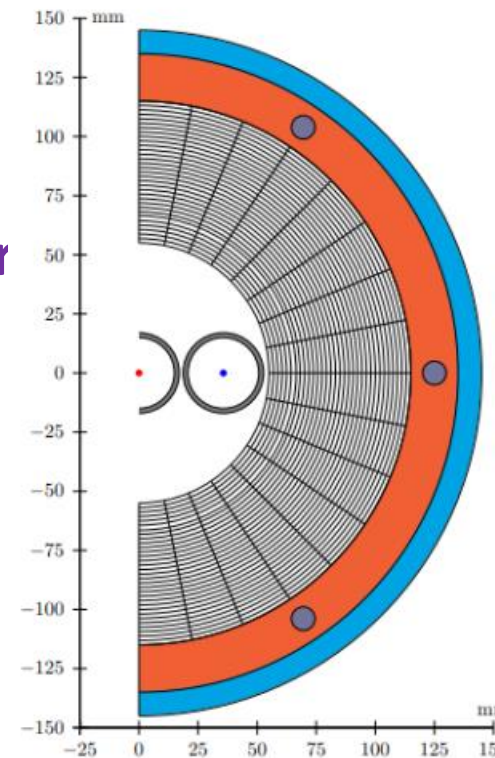
Physics rate: 200 kHz at Z pole / 40 MHz bunch crossing

- Initial thoughts: triggerless mode not too difficult

- But: very large backgrounds related to beam
  - Synchrotron Radiation
  - Incoherent Pairs Creation
  - Radiative Bhabhas (Brem)
  - Design of MDI very delicate: shieldings, back-scattering

- Occupancies actually not so small
  - Main issue for vertex detector and gaseous tracker
  - Work needed on frontend electronics to establish what can be done there
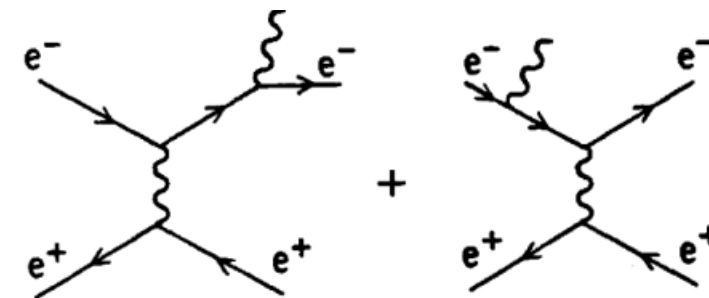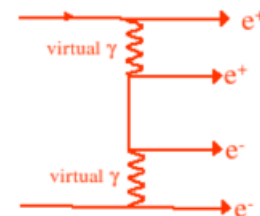 - Significant reductions necessary to make readout rates manageable
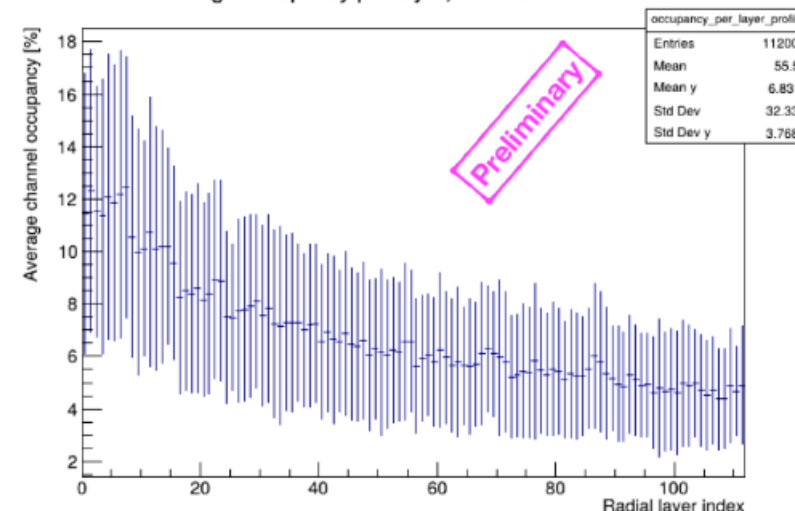
Breit-Wheeler   Bethe-Heitler   Landau-Lifshitz

Average occupancy per layer, 20 BXs ran 100 times

occupancy_per_layer_profile	
Entries	11200
Mean	55.5
Mean y	6.831
Std Dev	32.33
Std Dev y	3.768

Preliminary

French Laboratories and ALLEGRO Sub-Detectors as They Appeared in the EoI

- Vertex detector and MDI: **APC, CPPM, IP2I, IPHC, LPNHE**
- Tracker: **IJCLab**
- Timing layer: **IP2I, Irfu**
- ECAL**: APC, CPPM, IJCLab, LAPP, OMEGA**
- Software: **APC, IJCLab, LAPP**

- This list does not show all present R&D in our labs.
- This list is evolving. Potential new R&D/sub-detector/lab can join.
  - **LPSC** recently joined ECAL
- French community ready to take part in ALLEGRO conception and evaluation.