Expression of Interest for participating in the H2020 Innovation Pilot on detector technologies at accelerators

Title: R&D for future high-granularity noble liquid calorimetry

Participants (max. 6):

Name of the legal entity	Type (university, institute, laboratory, company)	Country
CERN	International Laboratory	CH
LAL Orsay (IN2P3)	Laboratory	F
OMEGA (IN2P3)	Laboratory	F
Prague Charles University	University	CZ
LAPP Annecy (IN2P3)	Laboratory	F
CPPM Marseille (IN2P3)	Laboratory	F

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Description: *(max. 1 page)*

High granularity noble liquid calorimetry will be essential for future accelerator experiments (stability of response, uniformity, radiation hardness, high resolution energy measurement, high position resolution, timing resolution, high granularity for 3D imaging, pile-up suppression, particle ID, jet sub-structure,…). It is part of the reference design of an FCC-hh experiment presented in the FCC CDR and also studied as one of the options for an FCC-ee experiment. Due to long-term maintainability considerations as well as upgradeability a fully passive calorimeter with read-out electronics sitting outside the cryostats is the preferred option due to possible access and hence maintainability during yearly technical stops, leading, however, to long transmission lines of the signals and a large number of signal feedthroughs. For an FCC-hh experiment the expected high radiation environment favours a location of the front-end electronics outside the calorimeter volume, shielded from the high radiation inside the inner tracker volume.

A sandwich of steel-plated lead absorbers and read-out + HV electrodes immersed in a bath of a cryogenic noble liquid (LAr or LKr), forming active gaps of 1-3mm is being studied for a future FCC calorimeter (see FCC CDR, https://fcc-cdr.web.cern.ch). The granularity of such noble liquid calorimeters can be easily adjusted to the needs by finely segmented read-out electrodes (multi-layer PCBs). Novel techniques such as particle flow reconstruction of particle showers as well as 3D imaging techniques require high transversal and longitudinal granularity. An R&D program has been proposed to design, simulate, produce and test such multi-layer PCBs as read-out electrodes. Special focus has to be given to the resulting signal attenuation, the electronics noise, the capacitances of the signal channels and the cross-talk between different channels.

The following project is proposed:

- 2020-2021: Simulation and design of a multi-layer read-out + HV electrode (PCB) for a possible noble-liquid calorimeter.
- 2022-2023: Production of up to three prototype electrode PCBs
- 2024-2025: Electrical measurements of electrodes (attenuation, capacitances, cross-talk) at room temperature.
- 2024-2025: Measurements including read-out electronics (preamplifier, shaper ASIC) at room temperature (and possibly in cryogenic temperatures).

Noble liquid calorimeters are widely used in high-energy physics. However, up to now, such calorimeters were limited in granularity and therefore not optimized for particle flow energy reconstruction of jets or 3D imaging. The novelty of this proposed R&D project is to increase the granularity of noble-liquid calorimeters combining herewith the excellent intrinsic energy resolution of such calorimeters with the possibility to use state-of-the-art reconstruction and particle ID algorithms. In addition, the timing resolution of such a calorimeter will be investigated being a possible tool to improve particle-flow algorithms in presence of pile-up in a hadronic machine.

Deliverables (max. 3): list the expected deliverable(s) of the proposed activities

- Deliverable 1: Design and simulation of read-out electrode (report) T0 + 1 year
- Deliverable 2: Production of prototypes of read-out electrode T0 + 2 years
- Deliverable 3: Read-out electrode characterisation, including some read-out electronics (report) T0 + 4 years

Budget estimate

- Physics Simulation to determine granularity goal and timing performance: 15PMs
- PCB design and simulation: 15PMs
- Prototype PCB production and testing: 12PMs (+50k€)
- Read-out electrode electrical measurements and tests: 14PMs (+20k€)
- Adaptation of read-out ASIC: 10PMs (+20k€)
- Read-out electrode measurements including read-out electronics: 14PMs (+20k€)

Total number of PMs	EC contribution (in kEUR) (a)	Matching funds (in kEUR) (b)	Full costs (in kEUR) (a) + (b)
80	250k€	~700 k€ (*) CERN (36 PM fellow + 12 PM CERN staff + 20k€ (material) + IN2P3 (16 PM technical staff+ 10 PM physicists) +40 k€ (travel and material) + 6 PM Prague	950 k€

(*) assuming an average 8 k€ / PM for CERN and IN2P3