Expression of Interest (EOI)

Laboratories of CNRS-IN2P3 (France)

Questionnaire

Please indicate the name of the contact person for this submission:

Carlos Muñoz-Camacho, IJCLab, carlos.munoz@ijclab.in2p3.fr

Please indicate all institutions collectively involved in this submission of interest:

IJCLab, Université Paris-Saclay, CNRS-IN2P3, Orsay, France
IPHC, Université de Strasbourg, CNRS-IN2P3, Strasbourg, France
LLR, CNRS-IN2P3, Ecole Polytechnique, Institut Polytechnique de Paris, Paris, France
OMEGA - Centre de Microélectronique, CNRS-IN2P3, Ecole Polytechnique, Palaiseau, France
SUBATECH, IMT Atlantique, Université de Nantes, CNRS-IN2P3, Nantes, France

Please indicate the items of interest for potential equipment cooperation:

The French experimental groups of CNRS/IN2P3 in hadronic physics have a long experience with equipment contributions to major international accelerator facilities, such as the LHC, HERA, RHIC or CEBAF. The groups assembled in this EoI have particular experience and interest to contribute to the future electron-ion collider (EIC) on calorimetry, tracking and specialized electronics. We seek to group our efforts in a limited number of detectors in order to assemble a meaningful contribution in the eyes of French funding agencies. We develop below our past experience with similar detectors, then describe our existing contributions to the EIC project and how we envision future cooperation.

LLR has a strong background in calorimeter design and construction. The lab made major contributions to the CMS ECAL, in the design of the mechanical support structures, as well as in the conception and construction of the hardware-level trigger system. The lab now plays a leading role in the high-granularity upgrade of the CMS endcap (EM & hadronic) calorimeter. This effort spans mechanical design considerations, hardware trigger design, as well as qualification of the read-out electronics, which are designed by the neighboring OMEGA laboratory. LLR is a long-standing member of the CALICE Collaboration, investigating high granularity calorimetry for the ILC.

The QGP group at SUBATECH has participated in the heavy ion programs at SPS and RHIC (PHENIX and STAR experiments). It has been strongly involved in the construction of the ALICE detector since 1996. First, with the construction of the ALICE muon spectrometer and the ALICE strip silicon detector and, since 2006, with the construction of the ALICE electromagnetic calorimeter. Today, the major activity is the physics program of the ALICE experiment. The end of the ALICE construction in 2008 was accompanied by a noticeable contribution to the online, reconstruction and analysis software. This has allowed to play a strong role in the most promising physics analyses at LHC, like jets, photons, quarkonia and open heavy flavors, that have been developed since 2009.

The R&D/Detectors Division of IJCLab (formerly IPNO) has extensive experience participating in the construction of detectors for hadron physics, namely various calorimeters and a neutron detector for Jefferson Lab experiments. In particular, the lab has been involved in recent years in the construction of three electromagnetic calorimeters:

- the "IC" (Inner Calorimeter) for CLAS, a compact octagonal array of 424 scintillating lead-tungstate crystals read out by APDs, for which IPNO provided the mechanical support, along with a temperature stabilization system, as well as the pre-amplifiers for the APDs;
- the HPS (Heavy Photon Search) calorimeter, for Hall B, with similar concept and design as the IC, built using the crystals recovered from the IC, for which IPNO designed and constructed the mechanical support structure;
- the NPS (Neutral Particle Spectrometer), composed by 1080 scintillating lead-tungstate crystals, read out by PMTs, and meant to work in a very high radiation environment. IPNO/IJCLab has contributed to this project with studies of the optical properties and of the radiation hardness of the crystals, as well as with the design of the mechanical structure.

IJCLab has also been involved in calorimetry generic R&D within the eRD1 consortium since 2014. The main focus has been the study of homogeneous solutions for high resolution electromagnetic calorimetry for the electron endcap of a future EIC detector. Crystals from different manufacturers (Crytur and SICCAS) have been characterized in terms of optical transmittance, light yield and radiation hardness. More recently, glass samples newly produced by the Vitreous State Laboratory at CUA have also been investigated and their properties compared against those of crystals.

Our group could participate in the design and construction of the electromagnetic calorimeter in the electron-going direction covering pseudo-rapidities between -4 and -1, in collaboration with other institutions within the EICUG (a dedicated EoI in this regard is being submitted separately). Our contribution could include preliminary engineering design, construction and beam testing of prototypes, as well as manufacturing some of the mechanical structure of the final detector.

Concerning readout electronics, our group has extensive experience in developing ASIC circuits. In particular, un ASIC developed for the LGAD (Low Gain Avalanche Diode) detectors of the HGTD (High Granularity Timing Detector) of ATLAS at LHC could be an excellent baseline to readout the Roman Pots of EIC, but also other detectors currently planned using LGAD technology (4D tracker, preshower, TOF...). Our group has recently joined the eRD24 consortium to help develop an ASIC to read AC-LGADs with very small pixel size (0.5x0.5 mm^2), required for the Roman Pots. This work can be extended further in the future and a dedicated EoI on this topic is being submitted separately.

The physics objectives at the EIC will require a very high performance tracking system, where excellent spatial resolution associated with a highly suppressed material budget will be key parameters driving the design of the sub-systems. CMOS Pixel Sensors (CPS) appear as natural candidates for this challenging component of the experimental set-up. They have already demonstrated their added value in heavy ion collisions within the STAR-HFT and are shown to be adapted to tracking systems combining more than 20,000 units in a tracker offering a detection area exceeding 10 square meters. The IPHC of Strasbourg has been a leading actor of the pioneering and development of this novel technology. It is presently realizing the CPS intended to equip the vertex detector of the CBM experiment at FAIR. In perspective of projects beyond this mid-term goal, such as future electron-positron colliders, it has started to prototype a newly available CMOS technology based on very small feature size (65 nm) within a consortium coordinated at CERN, and is preparing to start designing large surface (multi-reticulated) sensors which would allow sizable material budget reductions. IPHC's involvement in an EIC oriented tracker project would address the sensor design and tests.

Concerning ancillary detectors, the Accelerator Division of IJCLab may contribute to the design of a Compton Polarimetry and in particular to the laser system for which a precise control of the laser polarization is critical.

Finally, our groups have also extensive experience with simulations and have started an effort in view of the Yellow Report initiative. For this, we have developed a new generator for nuclear DVCS and made some jet simulations. We intend to continue these simulation projects, particularly on the physics side with the creation and improvement of event generators used to design detectors. This contribution could be significantly widened with detector simulations in the future for which we expect to have significant contributions as well.

Please indicate what the level of potential contributions are for each item of interest:

The main contribution to the project from our group will come in the form of in-kind labor contributions. This includes design and engineering of mechanical parts of equipment, design of boards and chips of readout electronics, prototype construction and tests, installation and commissioning of the experimental equipment, and Monte-Carlo simulation. A financial contribution for equipment is also expected, but the prospect for funding is limited. We are estimating that about 1M$ is a reasonable amount to expect over the full 10 years of design and construction. This will likely not fully cover construction costs of the equipment on which we will contribute. This financial contribution is expected to cover the construction of prototypes and minor elements of the equipment.

Please indicate what, if any, assumptions you made as coming from the EIC Project or the labs for your items of interest:

We assume that the EIC projects will cover the procurement of major elements of the equipment that involve important direct costs.

Please indicate the labor contribution for the EIC experimental equipment activities:

The time commitment over the 10 years of the project construction of members of our groups in the EIC efforts described in this EoI is anticipated to be as follows:

Institution Name	Staff Scientist	Postdoc	Graduate Student	Engineer	Designer	Technician	Total Sum
IJCLab	0.3	0.2	0.6	0.4	0.6	0.25	
	0.2	0.2				0.25	
	0.2					0.25	
	0.2					0.25	**3.9**
LLR	0.2	0.2	0.15	0.2			**0.75**
SUBATECH	0.3		0.15		0.2		**0.65**
IPHC	0.3			1.7			**2.0**
OMEGA				0.2			**0.2**
TOTAL	**1.7**	**0.6**	**0.9**	**2.5**	**0.8**	**1**	**7.5**

This table is filled with annual average full time equivalent (FTE) estimates over a period of 10 years corresponding to the full project from R&D to installation of the equipment in which we will be involved. Thus, a contribution of 0.1 corresponds to 1 year of FTE.

Please indicate if there are timing constraints to your submission:

Several of our institutions are directly involved in the upgrades of LHC and have constraining engagements for the coming years on hardware projects that limit our ability to rapidly redirect a significant work force to a new project. This particularly impacts the contributions of LLR and Subatech. Thus, we expect our global contribution to the EIC project to grow progressively in the coming years and peak around 2026-2027.

Please indicate any other information you feel will be helpful:

Within our consortium we have access to several machine shops and clean rooms that can be used for detector construction and prototype testing.

A strong irradiation facility (based on ^{60}Co sources) is also available to test the radiation damage of detector material and electronics. This facility can provide dose rates ranging from 6 to 5000 Gy/h. Thus, high total doses can be accumulated in a short period of time and the effect of different photon irradiation rates can also be studied.

Finally, IJCLab houses several beam facilities that can be used to further study the effects of radiation and perform detector beam tests. Firstly, a 50 MeV electron facility (ALTO) can provide up to 1 μA of electrons that can complement the irradiation tests made with photon sources. Secondly, a proton (and several ions) accelerator of the Van de Graff type (Tandem) can provide proton energies in the range of tenths of MeV. This facility is also readily available and will provide information on damage induced by hadrons.