Proposal for an international workshop at ECT in February 2013*

Physics at A Fixed Target ExpeRiment (AFTER) using the LHC beams

Organisers

◦ Stanley J. Brodsky	SLAC National Accelerator Laboratory, Stanford U. Menlo Park, CA 94025, USA email : sjbth@slac.stanford.edu
◦ Elena G. Ferreiro	Departamento de Física de Partículas, Universidade de Santiago de Compostela 15782 Santiago de Compostela, Spain email : elena@fpaxp1.usc.es
◦ Frédéric Fleuret	Laboratoire Leprince Ringuet, École Polytechnique, CNRS/IN2P3 91128 Palaiseau, France email : fleuret@in2p3.fr
◦ Jean-Philippe Lansberg (coordinator)	IPN Orsay, Université Paris-Sud, CNRS/IN2P3 91406 Orsay, France email : lansberg@in2p3.fr
◦ Andry Rakotozafindrabe	IRFU/SPhN, CEA Saclay 91191 Gif-sur-Yvette, France email : andry.rakotozafindrabe@cea.fr
◦ Ingo Schienbein	LPSC – Université Joseph Fourier - CNRS/IN2P3 38026 Grenoble, France email : schien@lpsc.in2p3.fr
◦ Ulrik Uggerhøj	Department of Physics and Astronomy, University of Aarhus DK-8000 Aarhus C, Denmark email : ulrik@phys.au.dk

Date and duration

After a first survey among the organizers and the likely key participants, we consider early February 2013 –either the first or the second week– to be the most timely for our workshop. This period corresponds to a lower activity of the experimental collaborations after the proton-lead runs in fall 2012, as well as being at the beginning of the long LHC shutdown for the energy upgrade. This is also not too close to the summer conferences for which our experimentalist colleagues usually commit to finish a number of analyses to be presented then.

We are also hopeful that the workshop will trigger an important interest within our theorist and experimentalist colleagues. We thus wish to have this workshop as early as possible in the year to inform them about this project as well as to receive their suggestions, remarks, warning as well as advice which would then guide the next activities in the advance of the project AFTER which is described below. One week seems to be the right duration with a morning session on a Saturday. If this is not possible because of organisational constraints from the ECT* side, we can also consider an extension of couple of days over another week.

Scientific proposal

Scientific context

Within the Standard Model of elementary-particle physics, Quantum ChromoDynamics (QCD) is the theory of strong interaction – one of the four fundamental interactions in physics. It binds quarks and gluons inside the nucleons as well as the nucleons inside the nuclei. While one understands QCD at short distances (the perturbative domain), phenomenon such as confinement of quarks and gluons in the nucleons is still not understood at a fundamental level. There is also no ab initio understanding of their dynamics within both nucleons and nuclei.

With the advent of the Large Hadron Collider (LHC) at CERN, a new era of particle and nuclear physics has begun. The LHC allows us to delve into QCD dynamics with protons and lead ions accelerated to a record nominal collision energy of 14 TeV and 5.5 TeV respectively – one order of magnitude beyond the previous colliders. The primary goals of the LHC were the discovery of the Higgs boson and the search for physics beyond the Standard Model. Two years after the first recorded collisions, the LHC has however also been recognised as an outstanding machine to study QCD with a remarkable precision, thanks to its large reaction rates and the modern detection techniques of its detectors.

Nevertheless, these detectors do not permit one to study processes producing very high longitudinal momentum particles. Such reactions are, however, particularly important in understanding the dynamics and confinement of quarks and gluons which carry the largest momentum fraction of the projectile particles.

By extracting a small fraction of the intense LHC beams thanks to a bent crystal to collide it with fixed targets, we can study produced particles without restrictions since the beam comes from one side only. Using the unprecedented energies of the LHC beams, this project, named AFTER for "A Fixed-Target ExperRiment", gives access to new domains of particle and nuclear physics complementing that of collider experiments, in particular the Brookhaven's Relativistic Heavy Ion Collider (RHIC) and the to-be Electron-ion colliders (EIC).

A few words on the project AFTER

The multi-TeV energy of the LHC beams would make this fixed-target physics program unique. As simple as it seems, the high energy LHC beams will allow for the most energetic fixed-target experiments ever performed. We believe that such a facility will be of much interest to a wide range of hadron, nuclear and particle physicists. The collision of the high energy LHC beams with fixed targets, including polarised and nuclei targets will greatly expand the range of fundamental physics phenomena accessible at CERN.

The fixed-target mode will permit one to carry out unprecedented precision measurements of hard QCD processes. In particular, the aim of AFTER is to study :

- rare configurations of the proton wave function which contain gluon or heavy-quarks with high momentum fraction ;
- the gluon content in the deuteron and neutron in a wide momentum-fraction range ;
- the correlation between the proton spin and the gluon angular momentum through the Sivers effect and novel spin correlations ;
- the production of W and Z bosons in their threshold domain ;
- the melting of excited heavy-quark bound states in the deconfined QCD phase in heavy-ion collisions ;

– the nucleus structure function for momentum fractions close to and above unity ;
– the deconfinement dynamics in the target-rest frame ;
– ultra-peripheral collisions in a fixed-target mode.

Compared to the RHIC experiments, which benefit from similar centre-of-mass energies, such a project will bear upon a huge luminosity –typical of a fixed-target set-up– and upon a complete versatility of target species. Compared to Electron-ion collider projects, this project will certainly be highly competitive in terms of cost and it will be of complementary design, with a specific focus on the study of parton content at large momentum fractions – in particular that in terms of gluons.

High-energy fixed-target experiments have already been discussed in the 90's, both at the European LHC and the American SSC. The main differences between this project and earlier ones are :

– the fact that the LHC is now built and runs –very well indeed–,
– bent-crystal beam-extraction techniques have now been successfully tested at the SPS and the Tevatron up to nearly 1 TeV and they will be tested on the LHC beams,
– a number of modern detection techniques have been developed in the meantime –in particular, ultra-granular detectors– and, finally,
– this project is, in essence, a multi-purpose experiment, not only focusing on one specific aspect of particle physics, as it was the case for the LHB project, for instance.

We believe it is well worth exploring this option and bringing our nuclear and particle physicist colleagues' attention to all these new physics opportunities. To do so, we plan

– to work out the detail of the physics case in adequacy with the current experimental possibilities –and limitations– ,
– to develop a first robust –but ambitious– design of the experiment and its assembly compliant to the physics case, and
– to advertise our project all over the world-physics community to create an experimental collaboration large enough to make this project viable and fruitful for the years to come.

The aim of the workshop

We are hopeful that such a workshop will meet in many respects the aim that the people involved in the project AFTER have. It will be an ideal way to advertise this project in which we strongly believe and which deserves to be discussed as widely as possible – beside the oral presentations that have just been accepted at Quark Matter 2012 and ICHEP 2012. Such workshop will also be a perfect set-up to start to deepen the discussions both on the physics case of AFTER and on a possible design of the detector – in the meantime, we will have obtained first simulations telling us the most important regions to cover for a couple of key measurements.

The workshop will also be a privileged moment for the people interested in AFTER from Europe, the US and China to gather and discuss the progress of our project. Since July 2011, we have tried to have a one day meeting each 3 or 4 months as well as a longer annual meeting. In this respect, we may christen such workshop at ECT* as the first *AFTER week*. Without any doubt, this would then be an important milestone in the early stage of this project. It would also display the European origin of the project while showing a strong wish for international contributions, be them theoretical or experimental.

To achieve this, we have thought about the tentative schedule detailed below as well as to the extensive key participants lists which encompass a number of experts in the domain.

Tentative schedule

We expect to have about 6 talks of 30 minutes per day and 2 sessions of 1.5 hour for round tables per day as well as time for informal discussions among the participants.

Day 1 : introduction to AFTER

- Key figures of AFTER : $\sqrt{s_{\rm NN}}$, luminosities, likely detectors acceptances, ...
- Flagship studies at AFTER
- Complementarity with other projects (eRHIC, ELIC, LHeC, E906, ...)
- Beam extraction by a bent crystal

Day 2 : physics in pp and pd collisions

- Gluon pdf reach in the proton and neutron
- Heavy-quark content in the nucleon
- W/Z production, Drell-Yan process

Day 3 : spin physics

- Anomalous Single Spin Asymmetries
- Single Spin Asymmetries with gluon sensitive probes
- Asymmetries with final state polarisation
- Target polarisation

Day 4 : cold and hot nuclear matter studies

- Nuclear matter studies in pA nucleus
- Quest for quarkonium sequential suppression
- Ultra-relativistic heavy-ion collisions from the perspective of the target rapidity domain

Day 5 : semi-diffractive physics, forward heavy-baryon production

- Ultra-peripheral collisions
- Diffractive heavy-baryon production
- Connections with cosmic ray studies

Day 6 : Summary and outlooks

Expected key participants & key speakers

(Extended list of key participants ; the 12 names in boldface are the expected key speakers)

1. R. Arnaldi, INFN Torino, Italy
2. **A. Andronic**, GSI Darmstadt, Germany
3. **M. Anselmino**, Torino U., Italy
4. D. Blaschke, Wroclaw U., Poland
5. **D. Boer**, Groningen U., The Netherlands

6. Z. Conesa del Valle, CERN, Switzerland
7. D. d'Enterria, CERN, Switzerland
8. C. Diaconu, CPPM Marseille, France
9. **C. Hadjidakis**, IPN Orsay, France
10. **P. Hoyer**, Helsinki U., Finland
11. P. Facccioli, LIP Lisbon, Portugal
12. **S. Klein**, LBNL, USA
13. L. Kluberg, LLR Palaiseau, France
14. M. Leitch, LANL, USA
15. G. Martinez, Subatech Nantes, France
16. **F. Olness**, SMU, USA
17. J.-C. Peng, Taiwan U. / UIU, USA
18. **S. Porteboeuf**, LPC Clermont-Ferrand, France
19. J.W. Qiu, BNL, USA
20. P. Robbe, LAL Orsay, France
21. J. Rojo, CERN, Switzerland
22. **H. Satz**, Bielefeld U, Germany
23. W. Scandale, CERN, Switzerland
24. **E. Scomparin**, INFN Torino, Italy
25. W. J. Stirling, Cambridge U., UK
26. **M. Strikman**, Penn State U., USA
27. Z. Tang, USTC Hefei, China
28. R. Ulrich, KITP Karlrushe, Germany
29. **R. Vogt**, LLNL & UC Davis, USA
30. J.X. Wang, IHEP Beijing, China

External support

We have secured funding to organise scientific meetings from the French CNRS via its interdisciplinary division as well as from the France-Stanford Center for Interdisciplinary Studies. Depending on specific regulations that we may cope with, we plan to use this money to support the attendance of a dozen of participants and/or to contribute to the overhead cost of ECT* such that the workshop would be a joint activity. We will have at least 4k€ at our disposal. Pending forthcoming funding decisions to be announced in June at the latest, such amount could be doubled. We also have the possibility to ask for a small support from the EU I3HP "Sapore Gravis" network of which 4 organisers are members. Finally, support can be also expected from the "Subprograma de Actuaciones Relativas a Infraestructuras Científicas Internacionales" of the Spanish Minister of Economy to be opened next July.

Aside from this, owing to the interest of our colleagues in the project AFTER and to the attractivity of attending a workshop in Trento, we expect that a number of them will accept to be self-supported participants as it has been the case for our previous one-day meetings in Orsay and Grenoble.