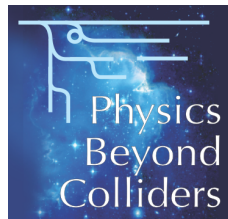
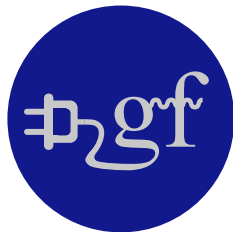


December 5, 2018

Gamma Factory for CERN

EPPSU ADDENDUM



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1 Interested community

The Gamma Factory (GF) initiative is of interest for the following scientific communities:

- the accelerator physics community;
- the particle physics community;
- the atomic, molecular and optical physics community;
- the nuclear physics community;
- the applied physics community.

The GF study group was created in February 2017. It includes scientists representing all the above communities. The group is, at present, composed of 55 researchers affiliated in 18 institutes from 9 countries, and it is steadily expanding. Its present members are listed below.

Members of Gamma Factory Study Group

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Center for Beam Physics, LBNL, Berkeley, USA.

2 Timeline

The Gamma Factory project described here is a sequence of the three development phases:

- Phase 1: Initial Study;
- Phase 2: SPS Proof of Principle Experiment (PoP);
- Phase 3: LHC Demonstrator Application.

The timelines for these phases are constrained by the already approved operation schedule of the CERN accelerators. The GF time planning minimises interference with the ongoing CERN research programme.

2.1 Phase 1: Initial Studies

The first phase of initial studies started in February 2017, with the creation of the GF study group embedded within the Physics Beyond Colliders (PBC) framework. It included the preparation and execution of dedicated SPS and LHC accelerator tests, performed over the years 2017–2018.

This phase will be completed by mid-2019, with a proposal of the GF proof-of-principle (PoP) SPS experiment. The timeline of this Initial Study phase, together with its milestones, superimposed on the LHC and SPS operation roadmap, is summarised in Fig. 1.

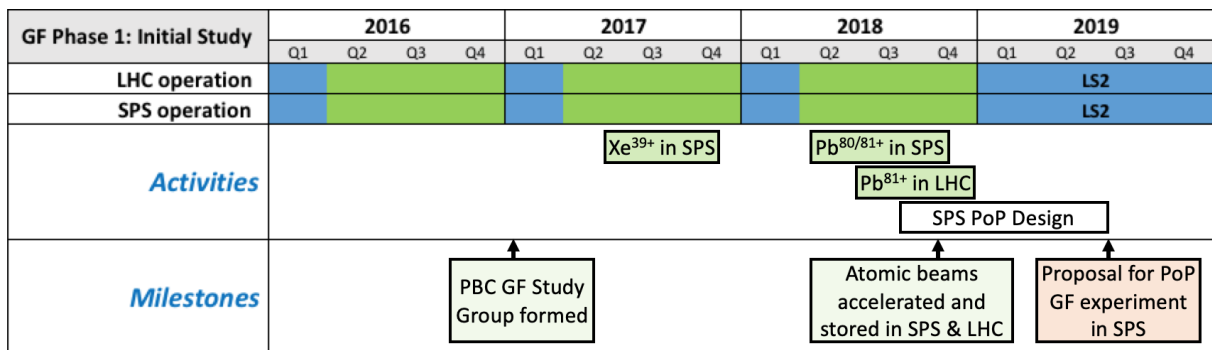


Fig. 1: The timeline of the Gamma Factory Initial Study, Phase 1 activities – years 2016–2019.

2.2 Phase 2: SPS Proof of Principle Experiment

If the SPS PoP proposal is accepted, the second phase of the project development will be activated to construct, install and operate this experiment. The planning of this phase includes:

1. the procurement and the “surface” tests of the vacuum chamber, laser-system, Fabry–Pérot (FP) cavity and remote controls;
2. the procurement of the photon-detector components;
3. the construction of the new ion stripper;
4. the installation of the vacuum chamber, laser-system, FP cavity and photon detection system in the Interaction Region (IR);
5. the installation of the ion stripper in the PS–SPS beam transfer line.

The installations are foreseen to take a place during the 2021/2022 winter Year End Technical Stop (YETS). Over the years 2022 and 2023, our plan is to have a series of Machine Development (MD) runs with the SPS Pb^{79+} beam to optimise the photon beam production efficiency and to evaluate efficiency of the various beam cooling schemes.

If operational experience with the PoP experiment, its results, and their extrapolation to the LHC running conditions, confirm the feasibility of the LHC-based GF, we plan to complete the second phase of the project by preparing, over the year 2023, the GF Technical Design Report (TDR) for an LHC Demonstrator Application. The timeline of the PoP phase of the project, together with its milestones, superimposed on the LHC and SPS operation road-map, is presented in Fig. 2.

GF Phase 2: SPS PoP	2020				2021				2022				2023															
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4												
LHC operation	LS2																											
SPS operation	LS2																											
Activities	Radiation test		Stripper construction		Laser procurement				Build and test FP system				Install in SPS				SPS PoP MD beam tests				SPS PoP MD beam tests				TDR			
Milestones	Validate Laser radiation tolerance				All equipment ready for SPS installation				System hardware and beam commissioned in SPS				Proof of GF concept and TDR launch															

Fig. 2: The timeline of the Gamma Factory SPS PoP experiment, Phase 2 activities – years 2020–2023.

2.3 Phase 3: LHC Demonstrator Application

The SPS PoP experiment should give key input for the third phase: a demonstration of a Gamma Factory Application in the LHC, with the much higher Lorentz- γ boost factor.

The timeline of the LHC Demonstrator Application phase of the project is, as long as the PoP experiment and specific LHC application are not finalised, hypothetical. We present in Fig. 3 an initial scenario for illustration, to indicate a possible timing of the laser and FP cavity installation in the LHC tunnel, which could be done in parallel to the installation of the HL-LHC upgrade components.

3 Project costs – Phase 1 and 2

The initial study phase of the project is being accomplished without a dedicated budget line. The estimated cost of Phase 2 of the project, the SPS PoP experiment, is outlined below. The cost of the LHC

GF Phase 3: LHC Demo	2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
LHC operation	LS3				LS3				LS3							
SPS operation					LS3											
<i>Activities</i>	Assemble collaboration				Component design and production				Install in LHC				Beam test			
					Demo expt. design		LHC modifications						LHC demo beam tests			
					Laser & FP design and procurement											
<i>Milestones</i>	LHC GF Demo TDR submitted				LHC GF Demo approved				Demo design complete				All equipment ready for LHC installation			
													γ produced by LHC Demo application			

Fig. 3: A potential timeline of a Gamma Factory LHC Demonstrator Application, Phase 3 activities – years 2024-2027.

Demonstrator Application Phase 3 will depend heavily on the specifics of the application tool chosen, since this will determine the laser technology, the interaction region and the beam extraction and transport design, as well as the need for any target and secondary beam lines. The cost of this can only be determined at the TDR stage, around the end of 2023.

Three items are expected to drive the cost of the SPS PoP experiment:

1. the design, production and installation of a new stripper in the PS–SPS transfer line;
2. the design, procurement and installation of the laser system and the FP cavity in the SPS tunnel;
3. the design, procurement and installation of the detection system of photons produced in collisions of laser light with ions.

In addition, there will be costs associated with the infrastructure and services needed for the ion stripper, the laser and the diagnostics (e.g. cabling, shielding) as well as some costs for the collaboration for the design study.

The preliminary cost estimates for the different sub-systems are summarised in Table 1.

Table 1: Preliminary cost estimates for the Gamma Factory SPS PoP experiment (Phase 2).

Item	Duration [months]	Cost [kCHF]
1 Stripping foil unit (design, assembly, tests, installation – in synergy with a foreseen stripper upgrade)	24	125
2 Laser radiation tests and stability measurements	4	70
3 FP cavity (optics, support, interface, vacuum system)	12	180
4 Laser system (oscillator, amplifier, injection line), electronics, controls, assembly, lab tests, shipping, installation	24	800
5 Photon detection system (design, detector, controls, vacuum chamber, assembly, tests, installation)	24	100
6 Infrastructure and services (cabling, supports, shielding)	12	80
7 Collaboration support (travel, subsistence)	48	80
Total	48	1435