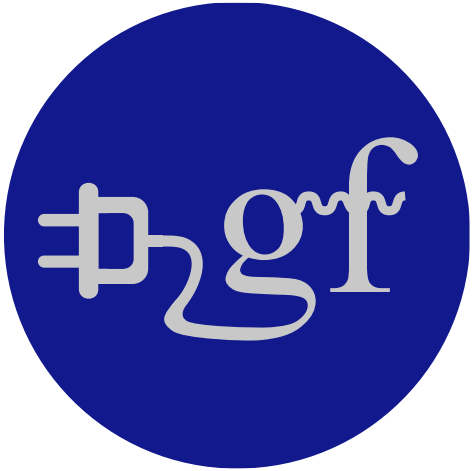
Short introduction to the GF activities

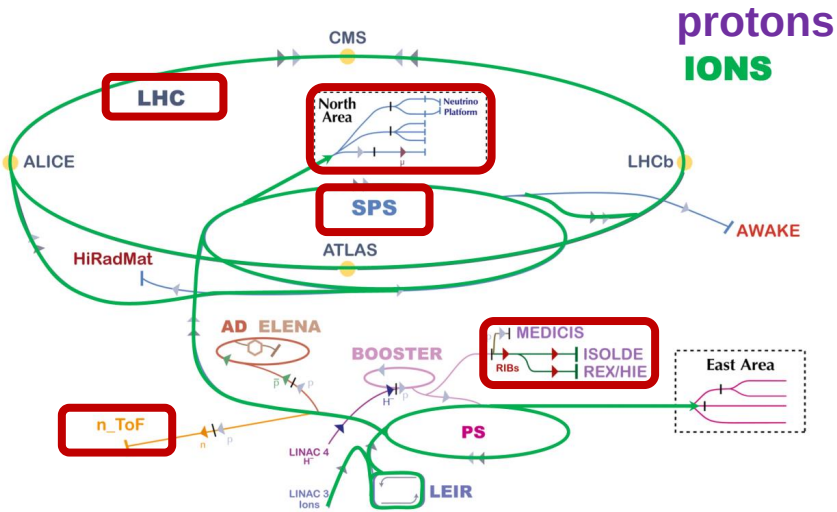


- **CERN, December the 11th, 2023**

- Mieczyslaw Witold Krasny

  Gamma Factory group leader
  LPNHE, CNRS and University Paris Sorbonne
  and CERN, BE-ABP

CERN experimental programme with proton and ion beams



The Gamma Factory proposal for CERN †

† An Executive Summary of the proposal addressed to the CERN management.

Mieczyslaw Witold Krasny*

LPNHE, Universités Paris VI et VII and CNRS–IN2P3, Paris, France

e-Print: 1511.07794 [hep-ex]

Gamma Factory goal:

extension of the CERN programme with beams of improved quality and intensity + unique GF research programme – both with "minor" accelerator infrastructure investment!

“Gamma Factory”

~100 physicists form 40 institutions have contributed so far to the Gamma Factory studies

A. Abramov[1], A. Afanasev[37], S.E. Alden[1], R. Alemany Fernandez[2], P.S. Antsiferov[3], A. Apyan[4], G. Arduini[2], D. Balabanski[34], R. Balkin[32], H. Bartosik[2], J. Berengut[5], E.G. Bessonov[6], N. Biancacci[2], J. Bieroń[7], A. Bogacz[8], A. Bosco[1], T. Brydges[36], R. Bruce[2], D. Budker[9,10], M. Bussmann[38], P. Constantin[34], K. Cassou[11], F. Castelli[12], I. Chaikovska[11], C. Curatolo[13], C. Curceanu[35], P. Czodrowski[2], A. Derevianko[14], K. Dupraz[11], Y. Dutheil[2], K. Dzierżęga[7], V. Fedosseev[2], V. Flambaum[25], S. Fritzsche[17], N. Fuster Martinez[2], S.M. Gibson[1], B. Goddard[2], M. Gorshteyn[20], A. Gorzawski[15,2], M.E. Granados[2], R. Hajima[26], T. Hayakawa[26], S. Hirlander[2], J. Jin[33], J.M. Jowett[2], F. Karbstein[39], R. Kersevan[2], M. Kowalska[2], M.W. Krasny[16,2], F. Kroeger[17], D. Kuchler[2], M. Lamont[2], T. Lefevre[2], T. Ma[32], D. Manglunki[2], B. Marsh[2], A. Martens[12], C. Michel[40] S. Miyamoto[31] J. Molson[2], D. Nichita[34], D. Nutarelli[11], L.J. Nevay[1], V. Pascalutsa[28], Y. Papaphilippou[2], A. Petrenko[18,2], V. Petrillo[12], L. Pinard[40] W. Płaczek[7], R.L. Ramjiawan[2], S. Redaelli[2], Y. Peinaud[11], S. Pustelny[7], S. Rochester[19], M. Safronova[29,30], D. Samoilenko[17], M. Sapinski[20], M. Schaumann[2], R. Scrivens[2], L. Serafini[12], V.P. Shevelko[6], Y. Soreq[32], T. Stoehlker[17], A. Surzhykov[21], I. Tolstikhina[6], F. Velotti[2], A. Viatkina[9] A.V. Volotka[17], G. Weber[17], W. Weiqiang[27] D. Winters[20], Y.K. Wu[22], C. Yin-Vallgren[2], M. Zanetti[23,13], F. Zimmermann[2], M.S. Zolotorev[24] and F. Zomer[11]

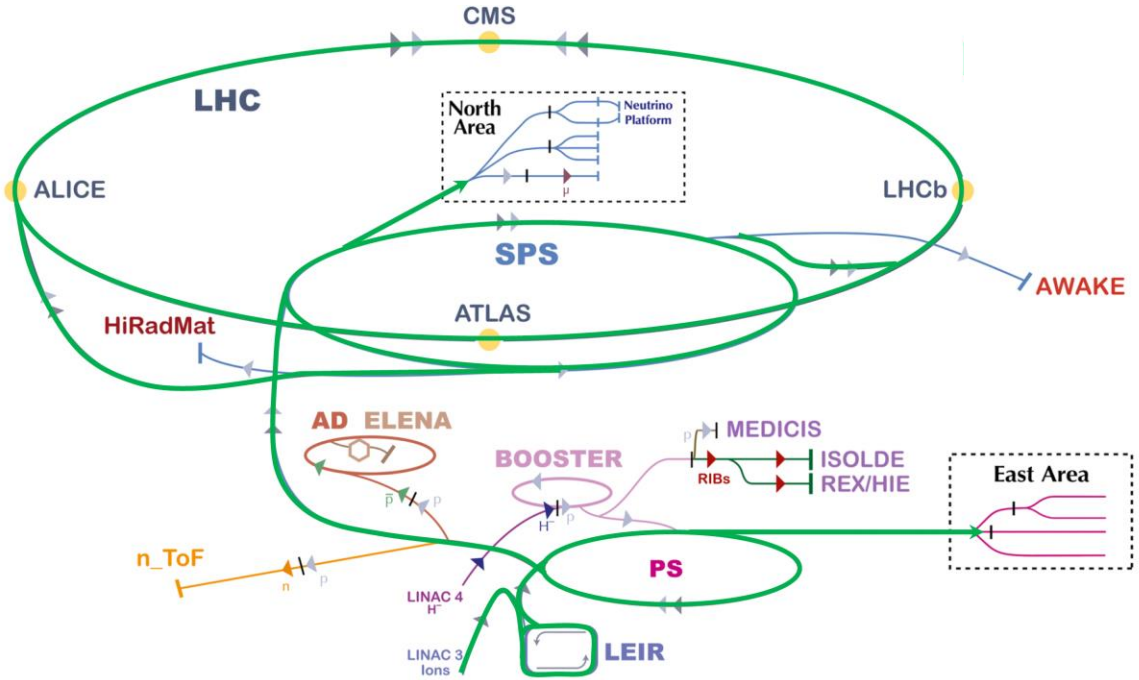
Gamma Factory studies are supported by the CERN Physics Beyond Colliders (PBC) framework.

More info on all the GF group activities:

https://indico.cern.ch/category/10874

*We acknowledge the crucial role of the CERN **PBC** support in bringing our accelerator tests, GF-PoP experiment design and software development to their present stage!*

Gamma Factory status

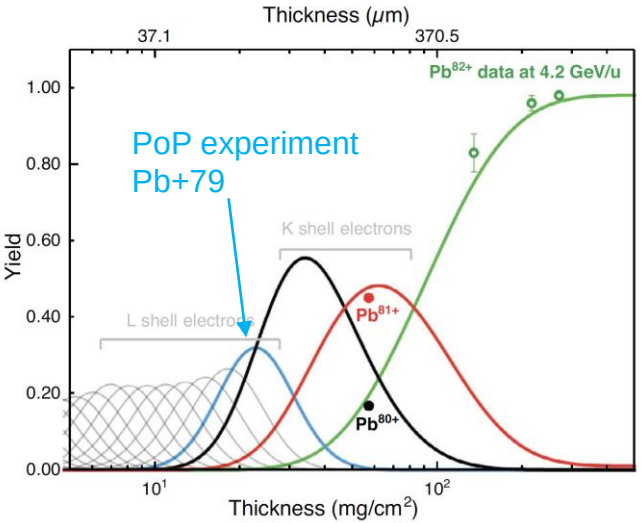


Gamma Factory accelerator and beam-storage requirements:

1. *Modification of the ion stripping scheme*
2. *Storage of atomic beams in the LHC*

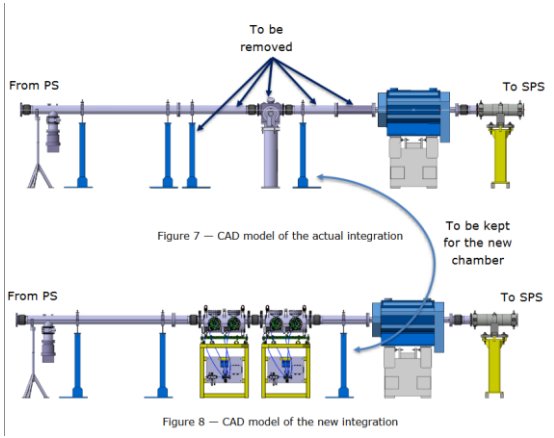
Requisite TT2 stripper system installed

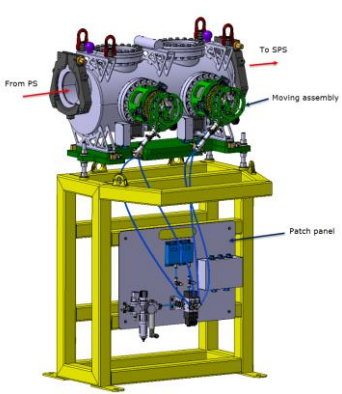
Stripping of Pb+54 ions in the TT2 PS-→ SPS transfer line



Charge-State Distributions of Highly Charged Lead Ions at Relativistic Collision Energies

Felix M. Kröger, Günter Weber, Simon Hirlaender, Reyes Alemany-Fernandez, Mieczyslaw W. Krasny, Thomas Stöhlker, Inga Yu. Tolstikhina, and Viacheslav P. Shevelko*





R. Alemany-Fernandez (BE.OP), E. Grenier-Boley and D. Baillard (SY.STI)

The two tanks of the new stripper system were installed during YETS 2021-2022 and YETS 2022-2023. Four stripper foil mechanisms operating at ~Hz frequency.

Stable storage of atomic beams in the LHC demonstrated

(Hydrogen-like Lead)

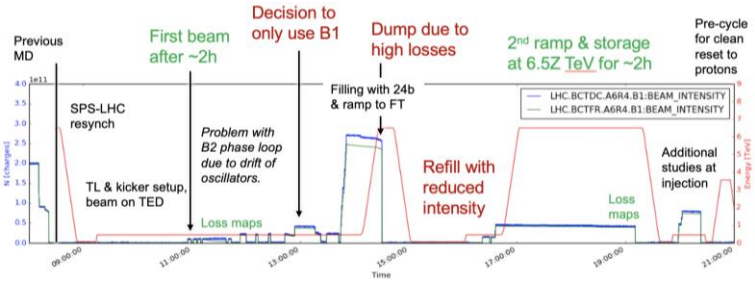
symmetry topics follow

A joint Fermilab/SLAC publication

LHC accelerates its first "atoms"

07/27/18 | By Sarah Charley

Lead atoms with a single remaining electron circulated in the Large Hadron Collider.



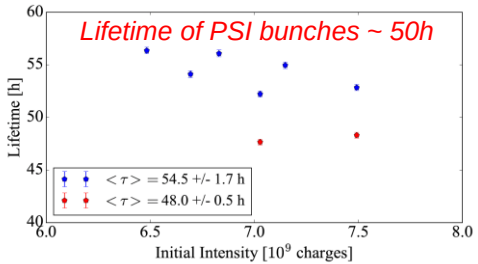
CERN-ACC-NOTE-2019-0012

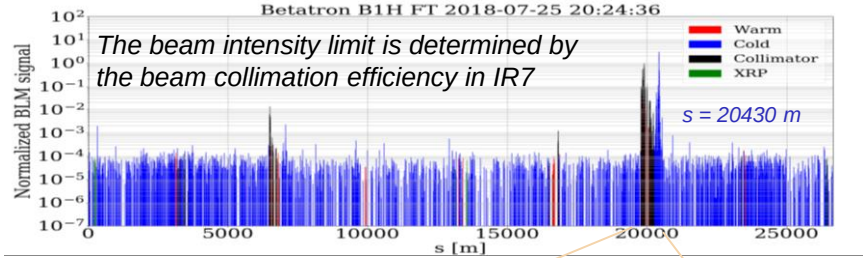
8 May 2019

Michaela.Schaumann@cern.ch

MD3284: Partially Stripped Ions in the LHC

M. Schaumann, A. Abramov, R. Alemany Fernandez, T. Argyropoulos, H. Bartosik, N. Biancacci, T. Bohl, C. Bracco, R. Bruce, S. Burger, K. Cornelis, N. Fuster Martinez, B. Goddard, A. Gorzawski, R. Giachino, G.H. Hemelsoet, S. Hirlaender, M. Jebramcik, J.M. Jowett, V. Kain, M.W. Krasny, J. Molson, G. Papotti, M. Solfaroli Camillocci, H. Timko, D. Valuch, F. Velotti, J. Wenninger
CERN, CH-1211 Geneva 23

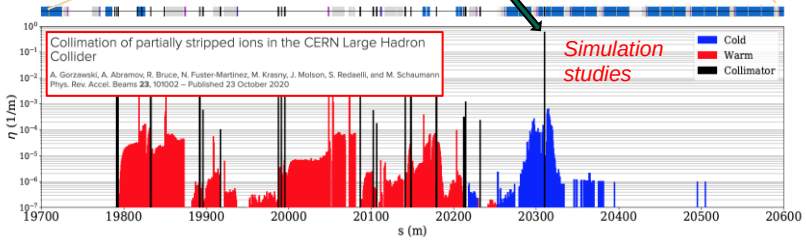




Mitigation strategies:

1. *Dispersion suppressor collimator (TCLD)*
2. *Crystal collimation*
3. *Laser collimation.*

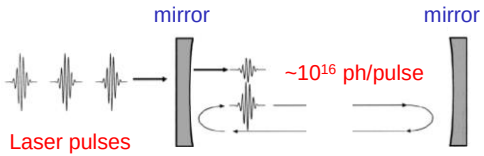
IR7 zoom

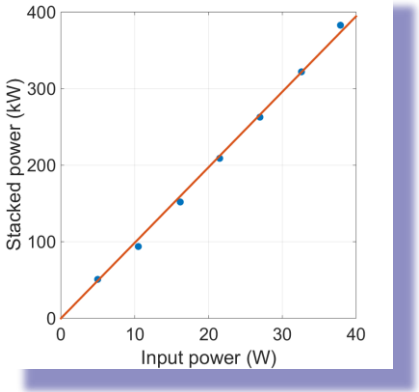


A dedicated LHC MD with crystal collimation of the PSI (H-like Pb) beam is a natural next step…

Fabry-Pérot (FP) resonators
and their integration in the electron storage rings

Fabry-Pérot resonator

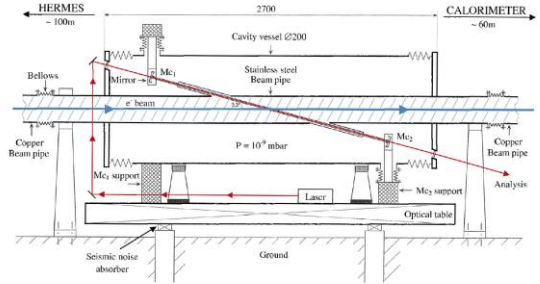




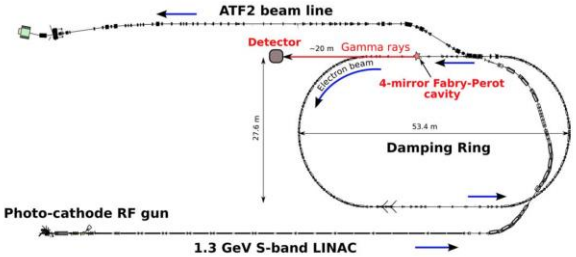
Amoudry L. et al., Applied Optics 59(2020)116

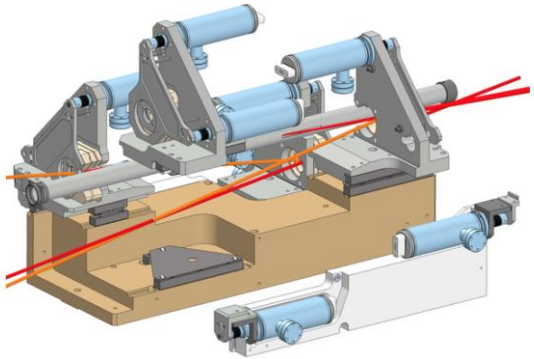
GF requirement:
< 5mJ pulses @ 40MHz,
(200kW photon beam)

HERA storage ring



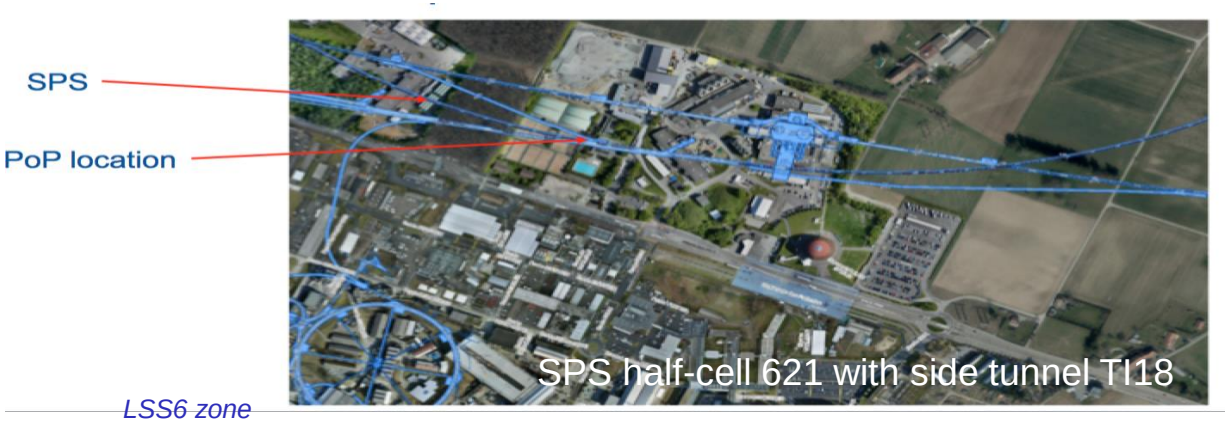
KEK – ATF ring





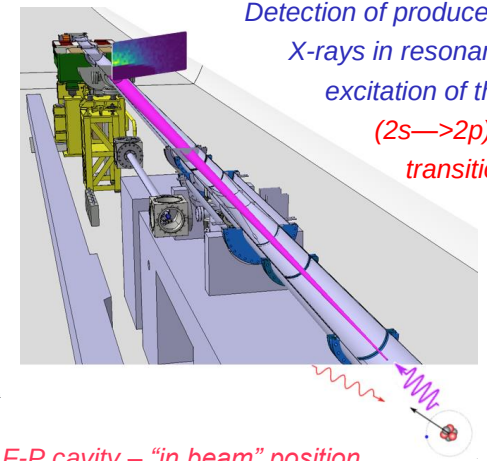
Proof-of-Principle experiment at SPS

Gamma Factory Proof-of-Principle (PoP) SPS experiment

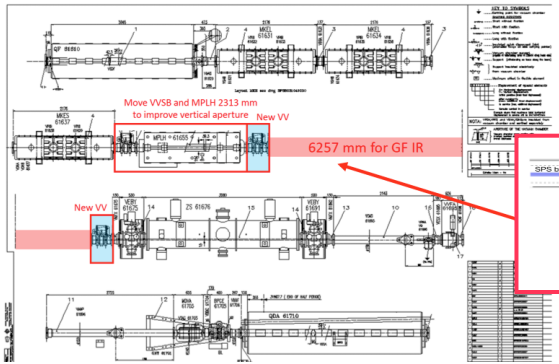


Lithium-like lead ion bunches in the SPS

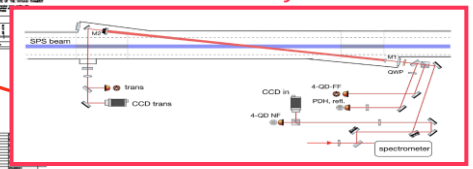
Detection of produced X-rays in resonant excitation of the $(2s—>2p)_{1/2}$ transition



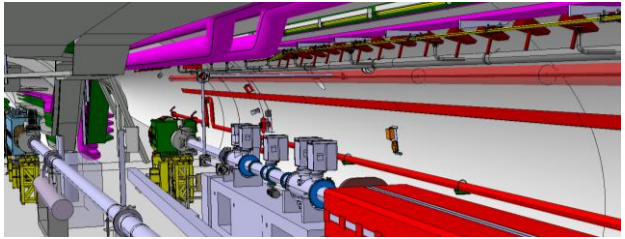
LSS6 zone



F-P cavity

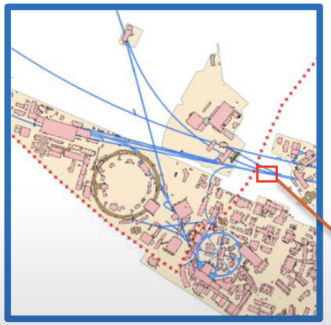


F-P cavity – "in beam" position



F-P cavity length – 3.75 m *-- vertically tilted by 2.6 degrees*

Environment



Gamma Factory Equipment in SPS tunnel

Hole between SPS and TI 18

TI 18

Old SPS to LEP beam transfer tunnel

GF PoP experiment laser room

SPS TS65

Smarteam Référence : ST1201804_01

The purpose of the GF SPS PoP experiment

1. Demonstrate that an adequate laser system (5mJ@40MHz) can be (remotely) operated in the high radiation field of the SPS.
2. Demonstrate that very high rates of photons are produced : almost all PSI's are excited in single collision of the PSI bunch with the laser pulse
3. Demonstrate stable and repeatable operation
4. Confront data and simulations
5. Demonstrate ion beam cooling: longitudinal and then transverse
6. Atomic physics measurements

Estimated cost of the experiment 2.5 MCHF

PoP experiment status

September 25, 2019

Gamma Factory

Proof-of-Principle Experiment

LETTER OF INTENT

Physics Beyond Colliders

CERN-SPSC-2019-031 / SPSC-I-253
25/09/2019

Gamma Factory Study Group

Contact persons:

M. W. Krasny, krasny@lpnhe.in2p3.fr, krasny@mail.cern.ch – **Gamma Factory team leader**

A. Martens, martens@lal.in2p3.fr – **Gamma Factory PoP experiment spokesperson**

Y. Dutheil, yann.dutheil@cern.ch – **Gamma Factory PoP study – CERN coordinator**

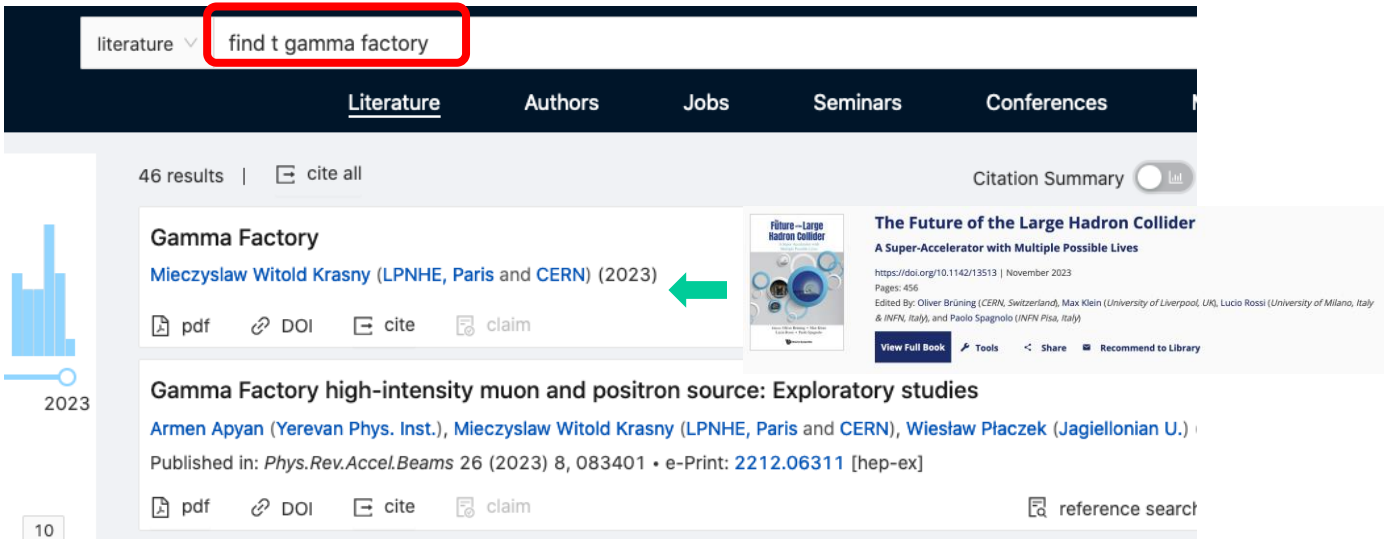
As received from the SPSC referees:

« The SPSC recognizes the Gamma Factory's potential to create a novel research tool, which may open the prospects for new research opportunities in a broad domain of basic and applied science at the LHC. »

- *Integration and operation model of the PoP experiment finalized*
- *Design of the laser light transport line finalized*
- *"Menhir Photonics" laser delivered on the 2nd November 2023*
- *Power test experiment with this laser, R&D amplifier, and new R&D mirrors at IJCLab (Orsay) ongoing*
- *Vibration tests in the SPS tunnel –- YETS 2024/2025*
- *Experiment installation – LS3 - 2026-2027*

Gamma Factory research programme

GF studies: recently published papers (INSPIRE)



Special issue of "Annalen der Physik" -- devoted to the GF physics highlights -- published in March 2022.

Examples of potential applications domains of the *Gamma Factory* research tools

- ***particle physics*** *(precision QED and EW studies, vacuum birefringence, Higgs physics in $\gamma\gamma$ collision mode, rare muon decays, precision neutrino physics, QCD-confinement studies, …);*
- ***nuclear physics*** *(nuclear spectroscopy, cross-talk of nuclear and atomic processes, GDR, nuclear photo-physics, photo-fission research, gamma polarimetry, physics of rare radioactive nuclides,…);*
- ***atomic physics*** *(highly charged atoms, electronic and muonic atoms, pionic and kaonic atoms);*
- ***astrophysics*** *(dark matter searches, gravitational waves detection, gravitational effects of cold particle beams, $^{16}O(\gamma,\alpha)^{12}C$ reaction and S-factors…);*
- ***fundamental physics*** *(studies of the basic symmetries of the universe, atomic interferometry,…);*
- ***accelerator physics*** *(beam cooling techniques, low emittance hadronic beams, plasma wake field acceleration, high intensity polarised positron and muon sources, beams of radioactive ions and neutrons, very narrow band, and flavour-tagged neutrino beams, neutron sources…);*
- ***applied physics*** *(**accelerator driven energy sources**, fusion research, medical isotopes and isomers production).*

Long term vision

A potential place of the Gamma Factory (GF) in the future CERN research programme

- *The **next** CERN **high-energy frontier** project (if ever constructed) may take **long time** to be approved, built and become operational, … unlikely before 2050-ties*

- *The **present** LHC **research programme** will certainly reach **earlier** (late 2030-ties?) its discovery **saturation** ($L_{int} \sim 0.5 L_{goal}$) -- little physics gain by a simple extending its pp/pA/AA running time*

- *A strong **need** will certainly arise for a **novel** multidisciplinary programme which could **re-use** ("co-use") the **existing** CERN facilities (including LHC) in **ways** and at **levels** that were **not** necessarily **thought** of when the machines were **designed***

***The Gamma Factory** research programme could fulfil such a role. It can exploit **the existing world unique opportunities** offered by the CERN accelerator complex and CERN's scientific infrastructure **(not available elsewhere)** to conduct new, diverse, and vibrant research in particle, nuclear, atomic, fundamental and applied physics with novel research tools and methods*

A vision of the LHC operation in in the post-HL-LHC phase