Towards SPS GF PoP Experiment

Overall concept, stages and procedure.

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with many thanks to everyone else on the very enthusiastic team!

Outline

- Main objectives for SPS PoP
- Overview of concept and layout
- Technical subsystems
- Experimental stages

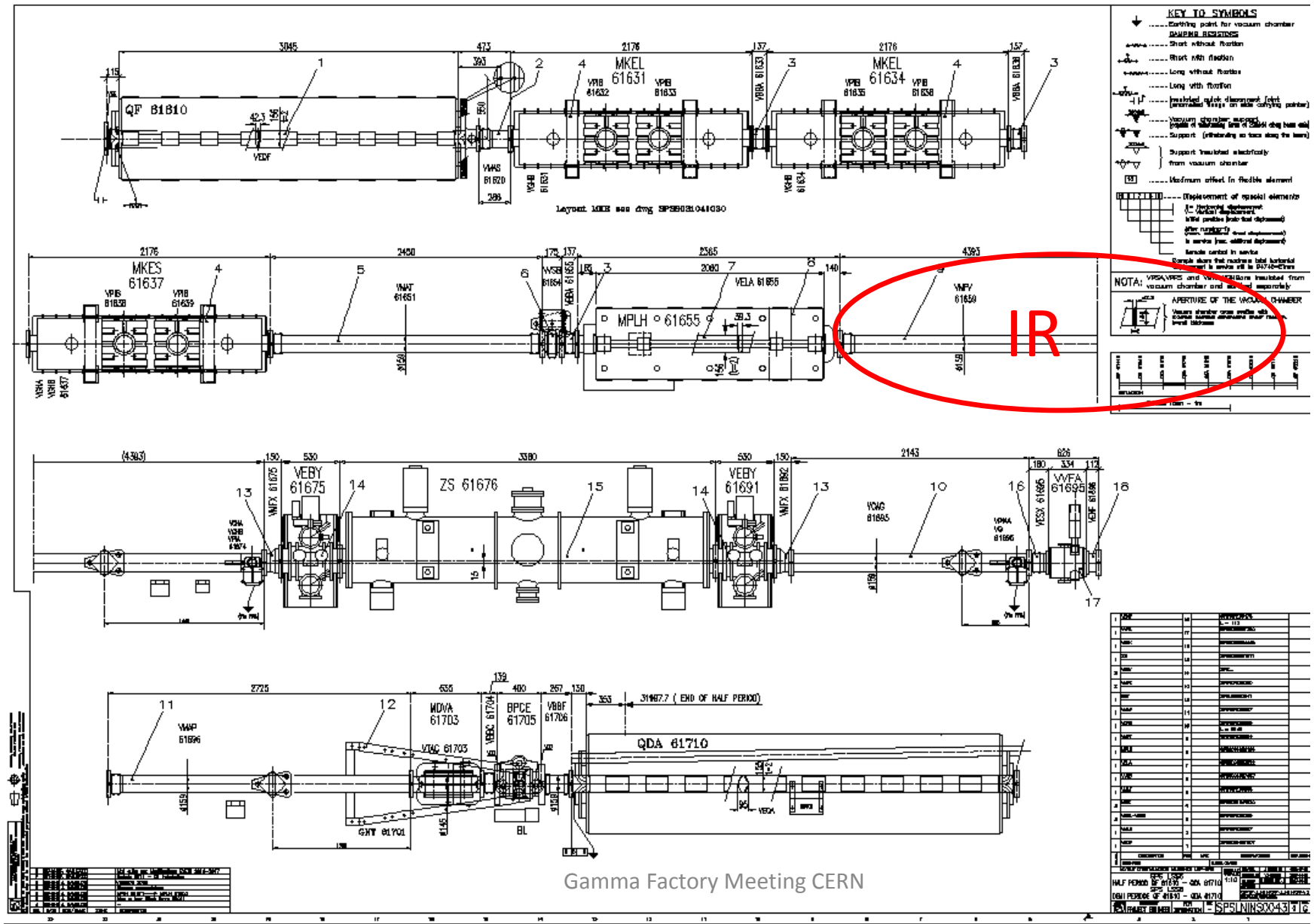
Main objectives

- Verify of simulations on rate of atomic excitation
- Demonstrate matching of characteristics of ion bunches to those of the laser bunches, match laser spectrum to width of the atomic excitation and achieve resonance for adequate fraction of ion population
- Measure of emitted X-rays, characterisation of flux and spectrum, and demonstration of photon extraction from the collision zone
- Demonstrate integration and operation of laser and Fabry-Perot cavity in a hadron storage ring

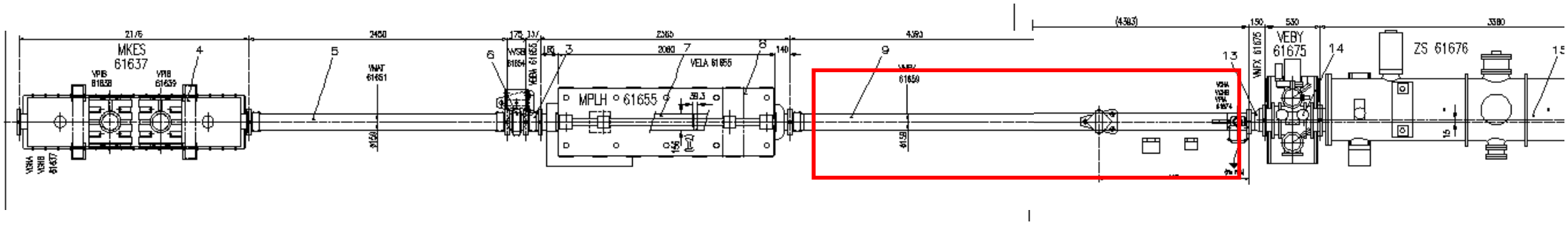
Ambition/complexity/cost cut-off

- Demonstrate laser cooling of relativistic beams and investigation of the different approaches
- Demonstrate feasibility of relativistic Atomic Physics measurements.

Laser-PSI interaction region: tentatively LSS6 616

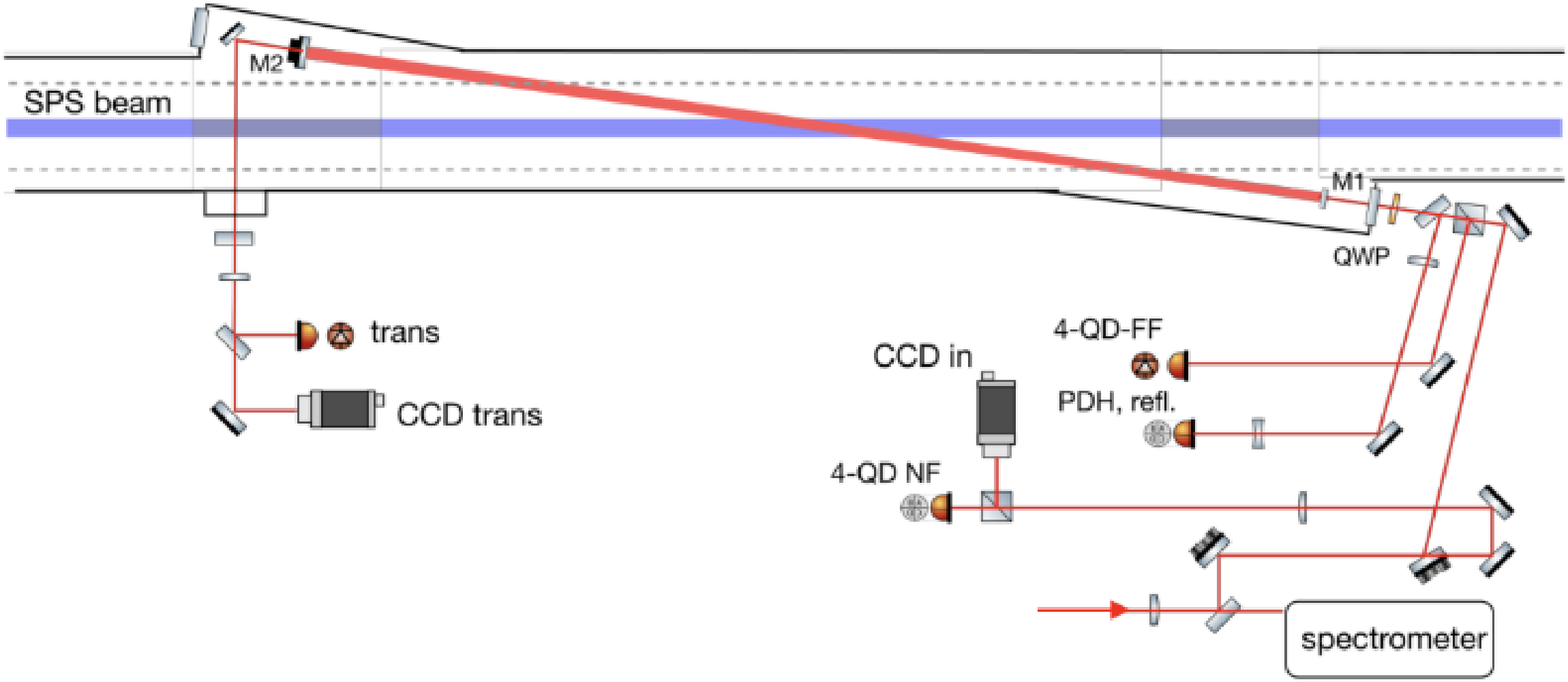


Laser-PSI interaction region: tentatively LSS6: 616



- About 4.4 m flange-flange between MPLH and ZS (VV)
- 2.6 degree cavity, **4 mJ** laser pulse energy at IR

FP cavity on SPS beam (vertical crossing?)



Status / open questions

- Ion species and transition: defined (pb79+, 2s→2p)
- Ion beam parameters: defined
- IR location: identified (IR6). Confirm?
- SPS optical parameters: Defined (for LSS6)
- IR layout & FP design: proposed 2.6 deg crossing.
- Laser characteristics: in progress.
- Timing & synchronisation aspects: in progress
- Radiation aspects: 2018 dosimetry measurements: in progress
- Simulation benchmarking: in progress
- Parameter list (including uncertainties): in progress
- Emitted photon distribution f(t): in progress
- PSI beam 6D evolution f(t): in progress
- Detector requirements: in progress
- Experimental procedures: in progress
- Atomic physics prospects: to define

Single-pass or optical resonator option?

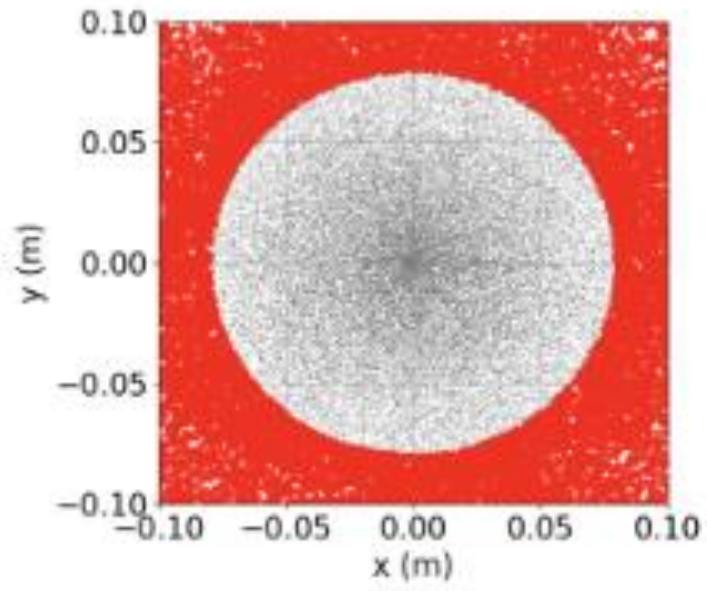
- An important concept to demonstrate is the FP cavity, since this is essential for an LHC application
- Highly desirable in the SPS PoP: **consider as baseline** since many aspects are contingent on this
- Adds extra complexity and potential R2E aspects for laser and cavity electronics
- Fallback solution of single pass to at least evaluate for performance and cost

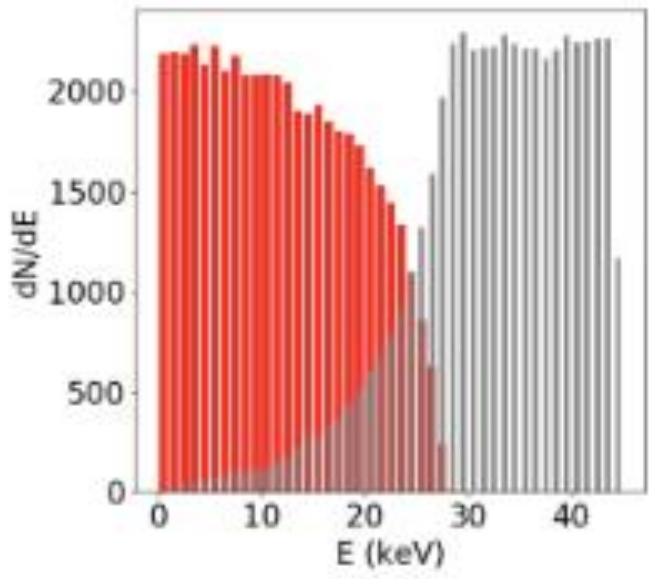
Draft PoP parameters

Parameter	Unit	FP cavity	Single-pass	Max uncertainly
Laser repetition frequency	MHz	0.0433	40	(locked to bunches)
Laser output pulse energy	μJ	1	5000	$\pm 10\%(?)$
Average laser power	W	216	40	$\pm 10\%(?)$
F_{rev} ($Pb^{79+}_{208}\gamma 86$)	Hz	43,373		± 0.02
Atomic transition energy $2s_{1/2} - 2p_{1/2}$	eV	230.76		± 0.004
Excited state lifetime (ion frame)	ps	76.57		$\pm 0.1(?)$
Excited state decay length (lab frame)	m	2.19		$\pm 0.01(?)$
Max. emitted photon energy (lab frame)	keV	44		$\pm 0.05(?)$
Laser - PSI beam crossing angle	deg	2.6		$\pm 0.05(?)$
Laser wavelength	nm	1034		$\pm 0.01(?)$
PSI relativistic γ		96.3		$\pm 0.1(?)$
RMS momentum spread in bunch		2×10^{-4}		$\pm 5 \times 10^{-5}$
Laser pulse energy at IR	mJ	5		$\pm 10\%(?)$

X-ray Detector

- Need to choose detector location:
  - Close to IR: small angle photons, close to beam, smaller impact on intermediate vacuum sectors
  - Far from IR: large angle photons, further from beam, larger impact on intermediate vacuum sectors
- What time/energy/spatial discrimination and range needed?





Objectives and deliverables

- Identify and answer remaining questions
- Produce and maintain list of all required parameters and inputs
- Produce specifications for subsystems
  - Laser
  - Interaction FP cavity
  - Detection systems
  - Controls, timing & SW
- Produce specifications for beam and operational aspects
  - Cycle
  - Beam type
- Develop a realistic experimental procedure
  - Finding resonance
  - Measuring key parameters
  - Demonstrating damping
- Define the detailed planning and budget

Collaboration tools (thanks Yann)

- SPS PoP mailing list (egroup): **PBC-acc-GammaFactory-SPSpop@cern.ch**
- A Microsoft workspace here
- An INDICO branch here
- SLACK (MatterMost clone) chatrooms here

Deadlines: phase 1

- Detailed Proposed: End June/July 2019 (~6 months)

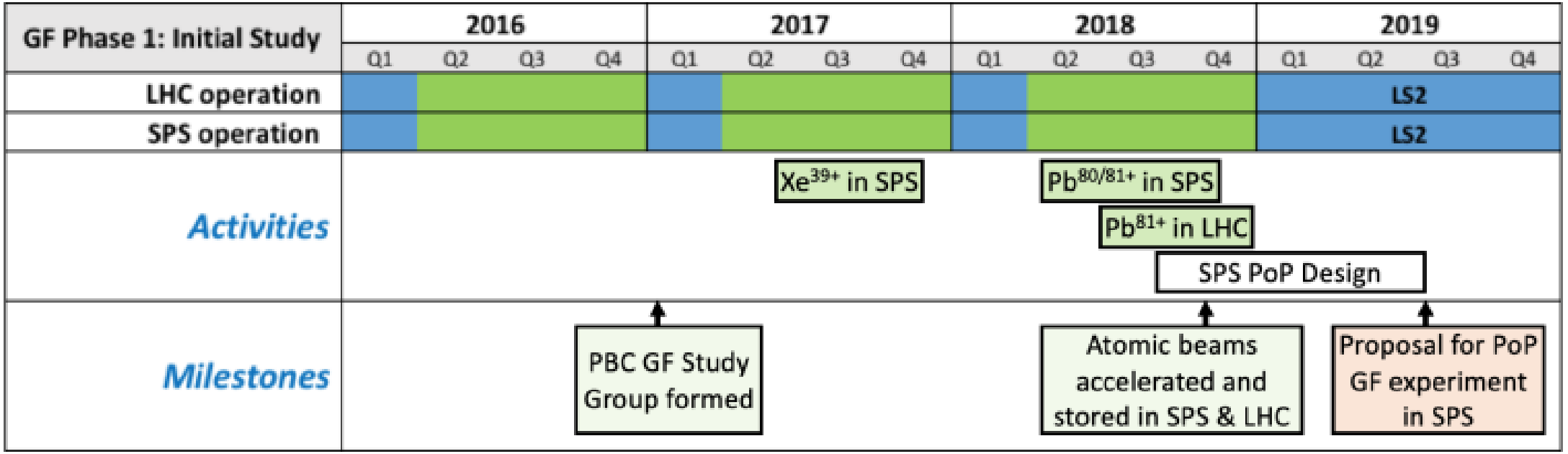


Fig. 1: The timeline of the Gamma Factory Initial Study, Phase 1 activities – years 2016–2019.

Deadlines: phase 2

- Systems ready for installation: End December 2021 (30 months)
- Beam tests: 2022 and 2023

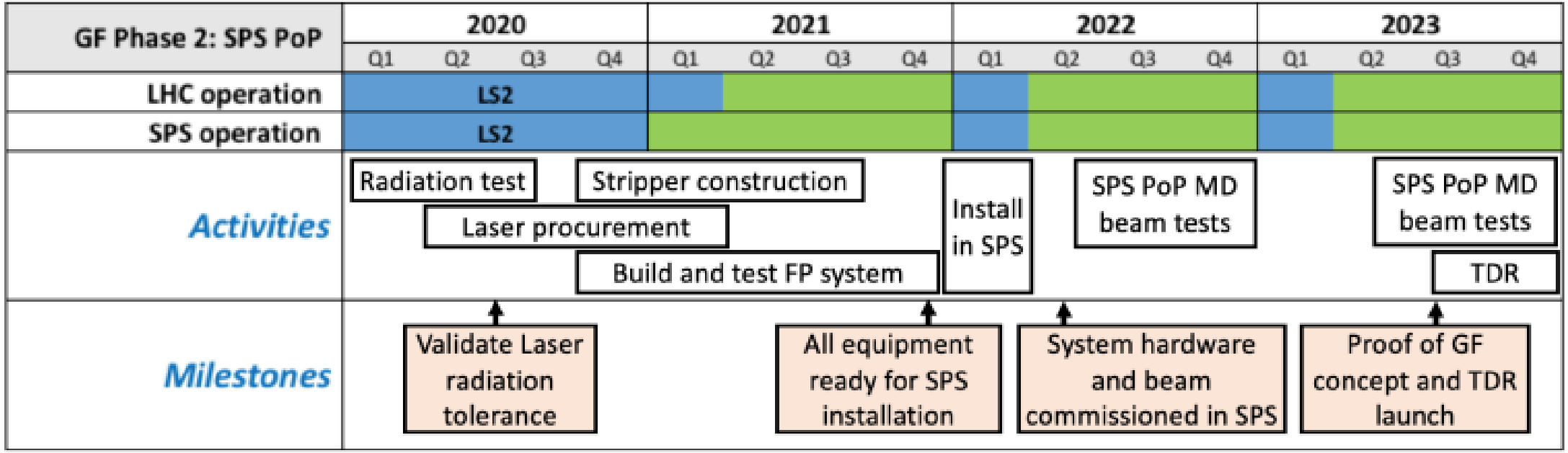


Fig. 2: The timeline of the Gamma Factory SPS PoP experiment, Phase 2 activities – years 2020–2023.

Timelines…

		DELIVERABLE		1	2	3	4	5	6	7	8	9	10	11	12
Simulatio	1.1	Define ion species and transition. Assign maximum uncertainty to energy values	Mar-19	K											
	1.2	Check impedance of FP cavity design and vacuum layout (for heating of mirrors and SPS beam)	Jul-19												
	1.3	Check impedance of detector (for heating and SPS beam)	Jul-19												
	1.4	Define photon flux at detector plans for Phases 1,2 & 3 (resonance finding, optimisation, cooling)	Mar-19	K											
	1.5	Simulate detector response for Phases 1,2 & 3 including background	Jul-19												
	1.6	Simulate longitudinal cooling and 6D distribution for Phase 3 (cooling)	Jul-19												
	1.7	Simulate beam observation response of Phase 3 (cooling)	Jul-19												
	1.8	Perform sensitivity analysis for Use-Case 1 (Monte-Carlo?) with foreseeable ripple & errors	Jul-19												
	1.9	Perform FLUKA simulations for radiation dose to laser and cavity electronics	Jul-19												
Specificat	2.1	Finalise ion beam parameters	Mar-19	K											
	2.2	Finalise IR location and layout (vacuum, physical integration)	Jul-19												
	2.3	Define shielding requirements	Jul-19												
	2.4	Finalise FP cavity requirements including impedance shielding	Jul-19												
	2.5	Finalise laser specification	Jul-19												
	2.6	Finalise operational SW/Control specification for Phases 1,2 & 3	Jul-19												
Document	12.1	Write-up of LOI	Jun-19												
	12.2	Write-up of Yellow Report	Jun-19												
	12.3	Generate SSR for IR/detector region	Sep-19												
	12.4	Generate ECR for IR/detector region	Jun-20												
	12.5	Final reporting of experimental results	Dec-23												

Today: afternoon

14:00 → 18:00 **PoP expriment** — 60-6-015 - Room Georges Cha...

Conveners: Brennan Goddard (CERN), Yann Dutheil (CERN)

14:00	**Overall concept, stages and procedure.** **Speaker**: Brennan Goddard (CERN)	40m	60-6-015 - Room Georges Cha...
14:40	**SPS accelerator aspects.** **Speaker**: Yann Dutheil (CERN)	20m	60-6-015 - Room Georges Cha...
15:00	**Ion transition parameters and their present uncertainties.** **Speaker**: Andrey Surzhykov	20m	60-6-015 - Room Georges Cha...
15:20	**Photon flux simulations.** **Speaker**: Camilla Curatolo (INFN - National Institute for Nuclear Physics)	20m	60-6-015 - Room Georges Cha...
15:40	**Coffee break**	30m	
16:10	**Impedance guidelines for the SPS** **Speaker**: Aaron Farricker (CERN)	1h	60-6-015 - Room Georges Cha...
17:10	**Bunch dynamic.** **Speaker**: Alexey Petrenko (Budker Institute of Nuclear Physics (RU))	30m	60-6-015 - Room Georges Cha...
17:40	**Laser system for single bunch, "photon production" option.** **Speaker**: Stephen Gibson (Royal Holloway, University of London)	20m	60-6-015 - Room Georges Cha...

Tomorrow: morning

09:00 → 12:50 **PoP experiment, cont.** — 60-6-015 - Room Georges Cha...

Conveners: Brennan Goddard (CERN), Yann Dutheil (CERN)

09:00	**Laser system(s) for single bunch and bunch train (cavity) "cooling proof" options.** **Speaker**: Dr Kevin CASSOU (LAL/CNRS)	40m	60-6-015 - Room Georges Cha...
09:40	**Radiation aspects.** **Speaker**: Ruben Garcia Alia (CERN)	40m	60-6-015 - Room Georges Cha...
10:20	**SPS-RF - Timing and synchronization.** **Speaker**: Wolfgang Hofle (CERN)	40m	60-6-015 - Room Georges Cha...
11:00	**Coffee break**	30m	
11:30	**Photon detection system(s) - photon production and beam cooling observation functions.** **Speaker**: Thibaut Lefevre (CERN)	40m	60-6-015 - Room Georges C...
12:10	**Experiment Layout and schedule** **Speaker**: Brennan Goddard (CERN)	40m	60-6-015 - Room Georges Cha...

13:00 → 15:00 **Lunch Break** — 2h

15:00 → 19:00 **SPS Visit**

Key questions

- Laser spectral, temporal and spatial characteristics
- Laser and FP cavity electronics location and radiation resistance
- Impedance aspects (on beam and on cavity)
- Photon detector specification and design
- Timing and synch to SPS RF
- Experimental uncertainties and procedure for the 3 “phases”
- Expected cooling (realistic spectrum, jitter, heating) and observable(s)
- Atomic physics?