



# Physics Beyond Colliders and link with ISOLDE

*pbc.web.cern.ch*

# Physics Beyond Colliders CERN Study Group

2nd edition: new mandate, modified structure and widened scope

*"The main goal of the Study Group remains to explore the opportunities offered by CERN's unique accelerator complex, its scientific and technical infrastructure, and its know-how in accelerator and detector science and technology, to address today's outstanding questions in particle physics through initiatives that complement the goals of the main experiments of the Laboratory's collider programme.*

*Examples of physics objectives include dedicated experiments for studies of rare processes and searches for feebly interacting particles.*

*The physics objectives also include projects aimed at addressing fundamental particle physics questions using the experimental techniques of nuclear, atomic, and astroparticle physics, as well as emerging technologies such as quantum sensors, that would benefit from the contribution of CERN competences and expertise.*

*The study group will primarily investigate, and, where appropriate, provide support to, projects expected to be sited at CERN. The study group may also examine ideas and provide initial support for contributions to projects external to CERN. The study group is also expected to act as a central forum for exchanges between the PBC experimental community and theorists for assessment of the physics reach of the proposed projects in a global landscape. "*

# Physics Beyond Colliders CERN Study Group

The PBC study group will act as CERN's initial portal for new ideas which may come in spontaneously or through specific calls launched by the PBC coordination team. The group will facilitate and support an initial evaluation of the relevance and technical feasibility of the ideas in a global context, and will regularly inform the CERN scientific committees (INTC, SPSC or LHCC) about their findings. Where appropriate, oversight of PBC studies will be passed to the relevant CERN scientific committee once they are adequately mature for scrutiny and review of possible implementation.

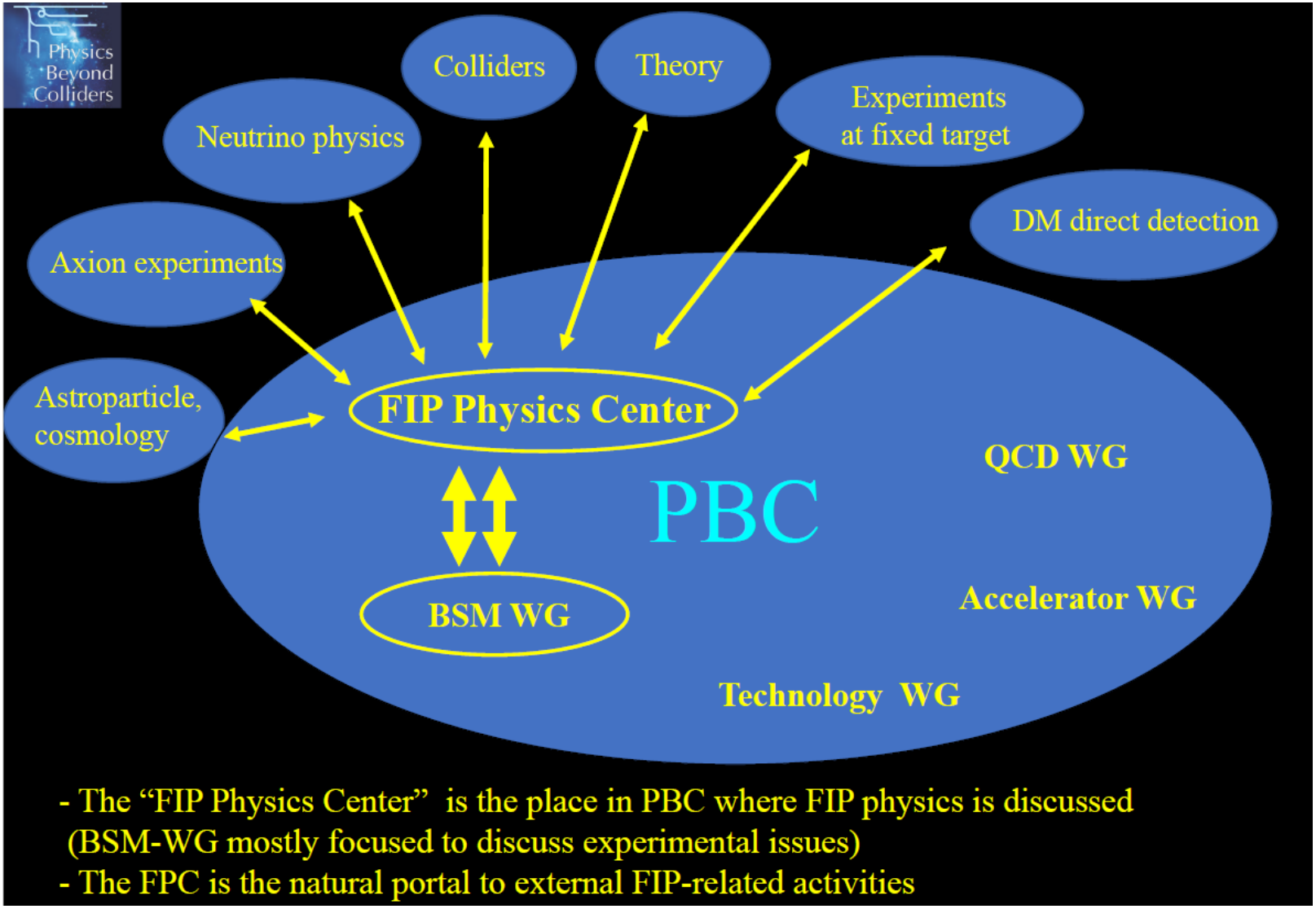
**WG content, project representatives, conveners being finalized in close relation with Scientific Committees and the community**

**3 MCHF/year secured in the CERN Medium Term Plan for PBC support**

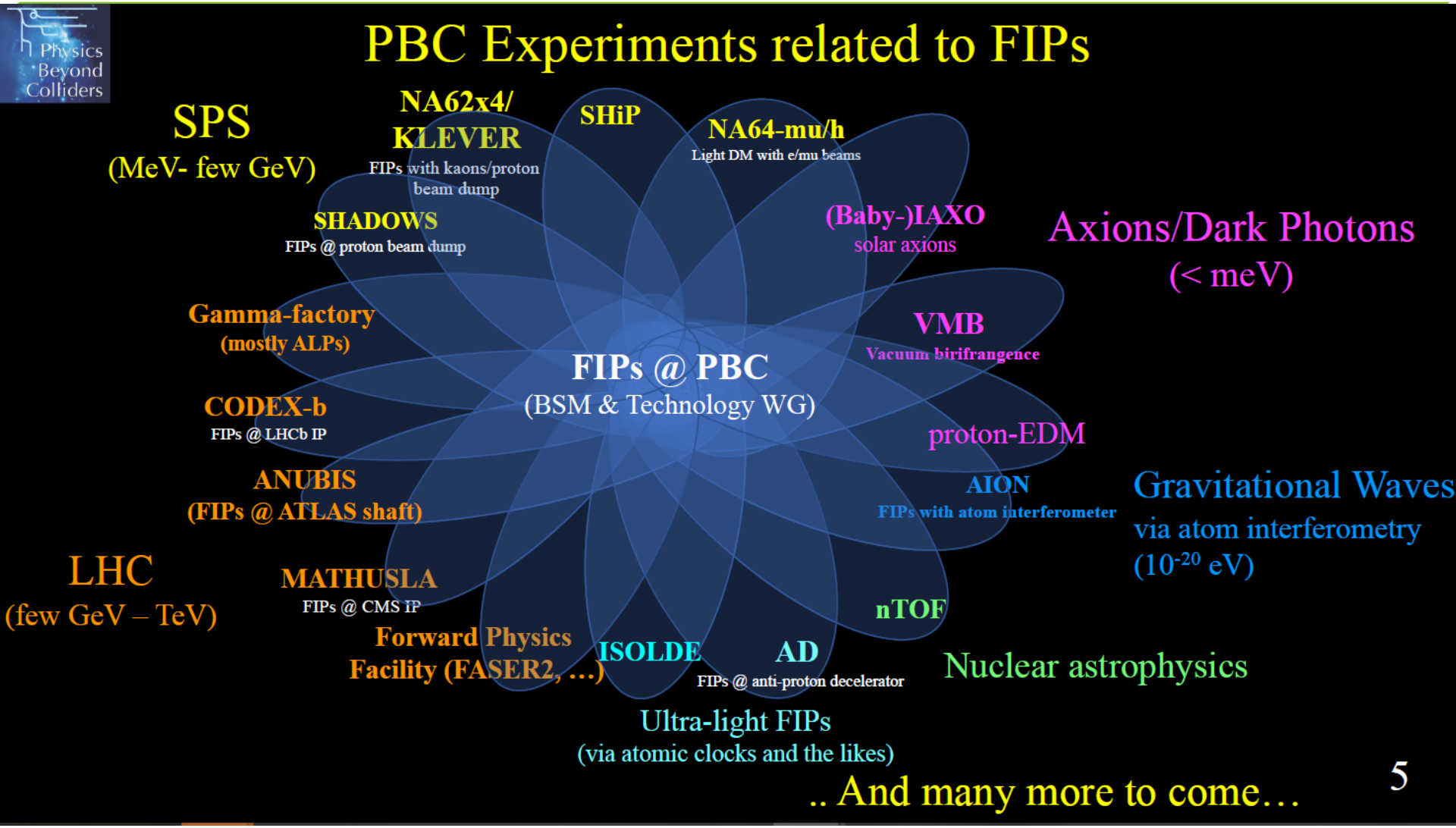
**PBC – personal summary:**

- Aim: support new, not yet mature ideas in fundamental physics
- Exchange with theorists to understand implication of measurements
- Possibility of small funds (PhD, post-doc) for projects accepted by the PBC committee
- Group still being created – chance for ISOLDE to be involved/visible

# PBC organisation



# Feebly interacting particles Physics Center




From G. Lafranchi

# PBC and ISOLDE

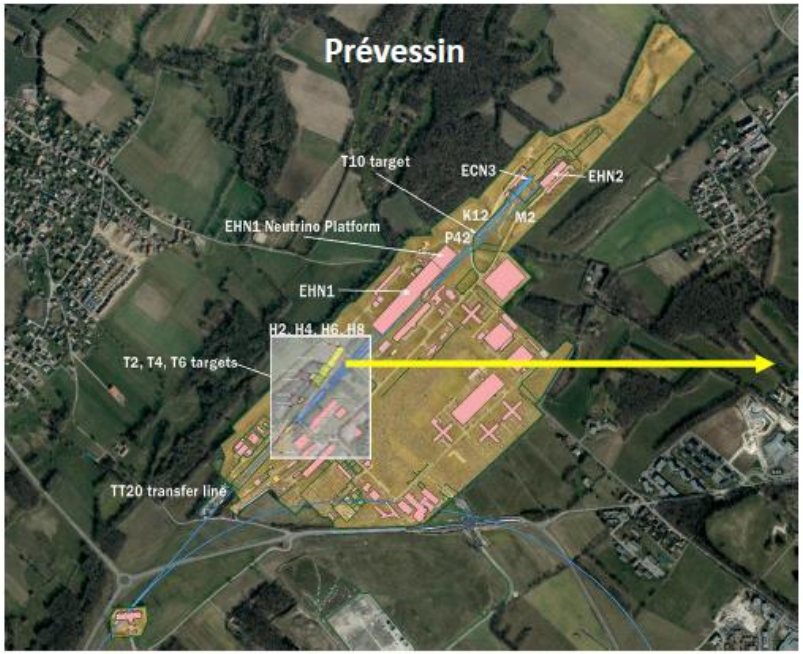
- Following informal discussions with PBC key persons: C. Vallee, J. Jaeck, G. Lafranchi, G. Arduini
- Aim:
  - represent ISOLDE fundamental studies: make people aware of what we do
  - Make/strengthen the physics case for EPIC
  - Connect/discuss implications of our studies with theorists
  - Profit from small funds for feasibility studies (experiments, facility: new experimental hall?)
- Idea:
  - 1 ISOLDE representative in Beyond Standard Moment Working Group - discussions on feasibility of the projects (and decision on financial support)
  - 1 ISOLDE representative in Feebly Interacting Particles Physics Center – more theory-oriented

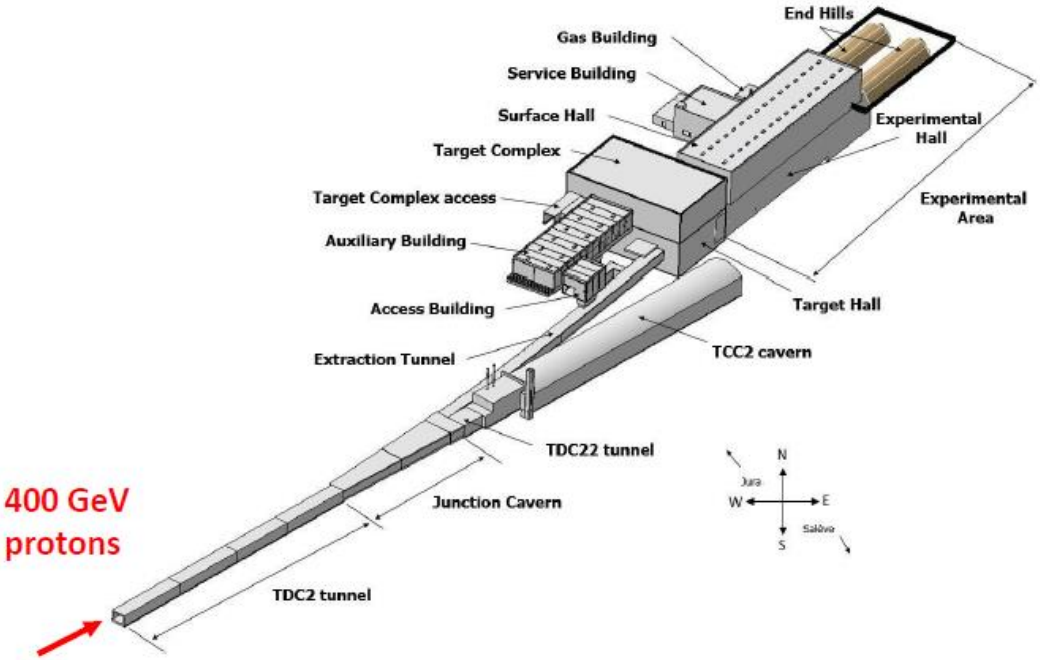
# Backup

# Supported projects: facilities

## PROTON BEAM DUMP FACILITY

**Comprehensive Design Study done within PBC**




**Continued R&D towards TDR for next EPPSU:**

*Slow extraction, target design, cost optimization incl. alternative siting (CNGS, West Area)*

→ of general interest for intensity upgrades of other CERN extracted beams

# Organisation


Beam Dump Facility

Conventional Beams

LHC – Fixed Target

Technology

PBC-A&T
Committee

Civil Engineering, Integration,
Radiation Protection

Accelerator Complex
Capabilities

Forward Physics Facility

Gamma Factory

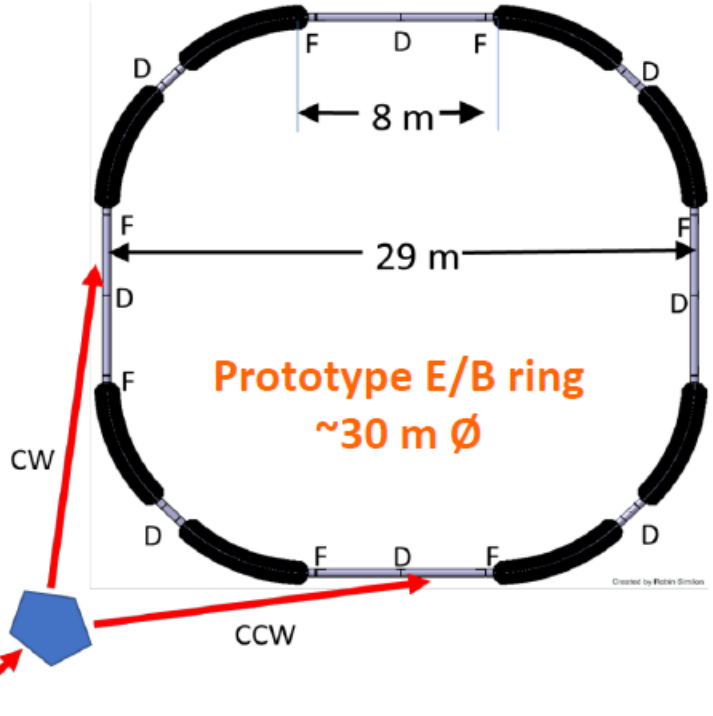
Proto-EDM

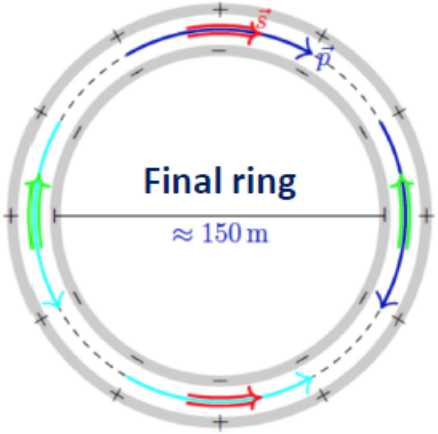
# Supported projects: facilities

## PROTON EDM RING

**COSY at Jülich supported by EPPSU as possible site for developing the project**

Ongoing precursor experiment at Jülich (magnetic ring)




Design sensitivity: 4. $10^{-29}$ e.cm

TDR for prototype ring in preparation by CPEDM Collaboration (incl. CERN)

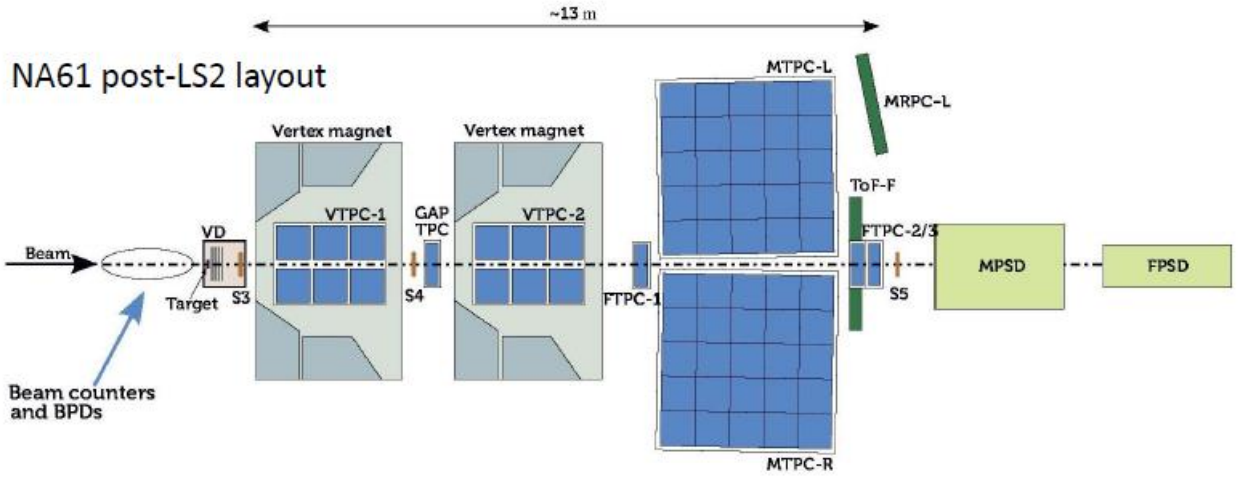
*Many systematics issues to be solved: lattice, deflectors, RF cavities, B-shield, BPMs…*

# Supported projects: QCD

## NA61++

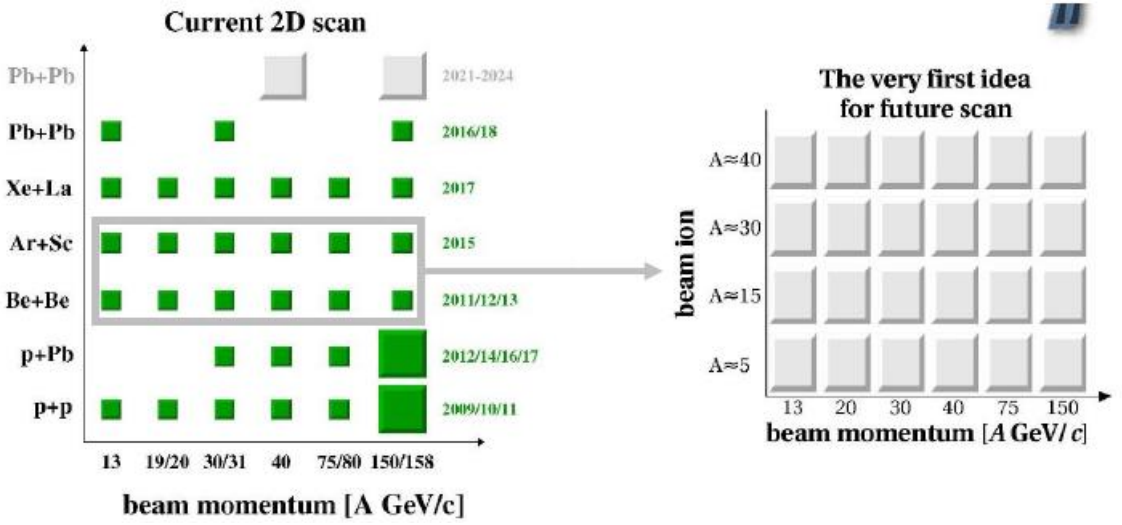
**Post-LS2:**

- ***Successful upgrades to study open charm close to expected CP-region.***
- Also unique measurements for ν-beams and cosmic rays
- ***To be followed by SPSC***




**Post-LS3:** ***(preliminary ideas)***

- ***Finer grain 2-D scan to study onset of fireball***
- Antiproton and low-E beams for baryon stopping studies
- Continued measurements for ν-beams and cosmic rays
- ***To be followed by PBC***

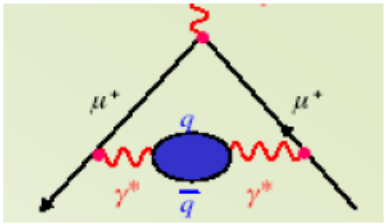


# Supported projects: QCD

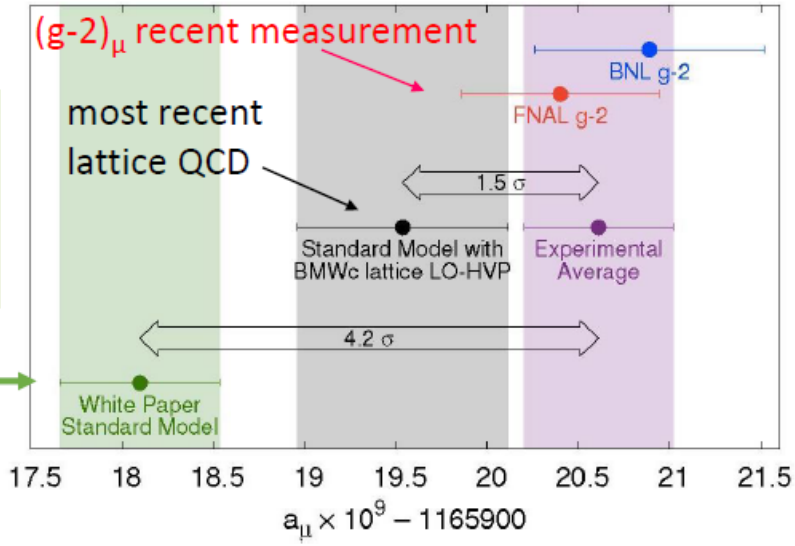
*New idea introduced within PBC:*

**Direct measurement of HVP contribution to $(g-2)_\mu$ with μ-e elastic scattering**

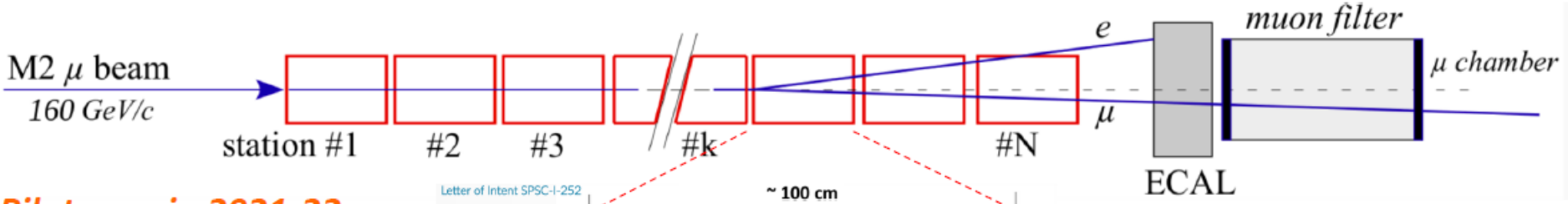
**MUonE**




**Complementary to prediction based on dispersion relation with $e^+e^-$ data**

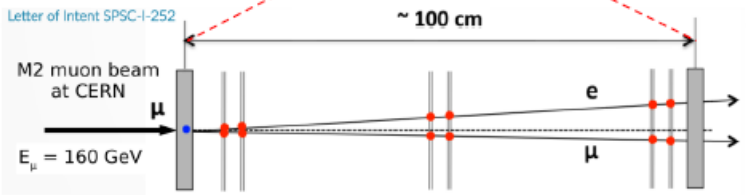



*Very challenging experimentally:*
*$10^{-5}$ precision required on cross-section*



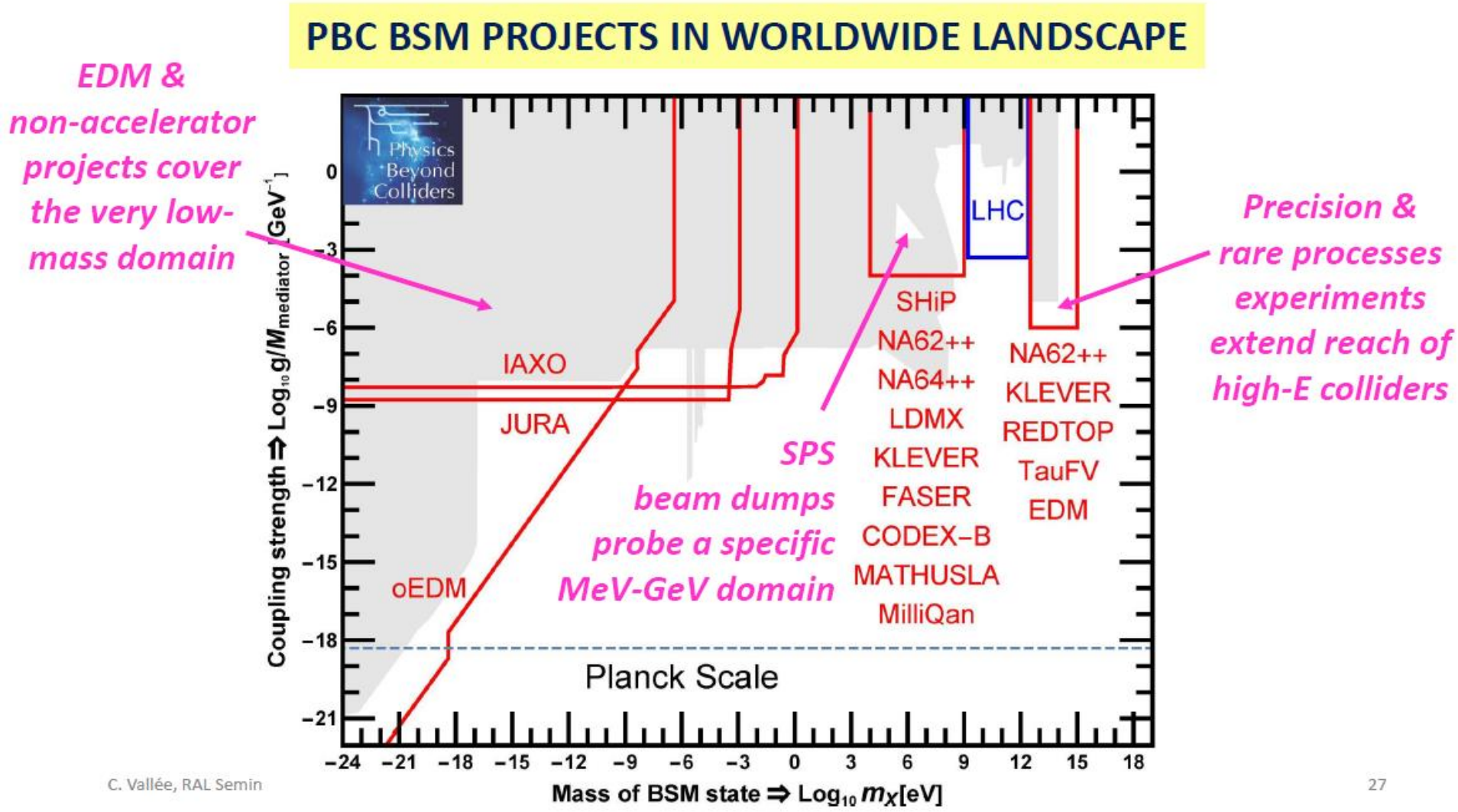

*Pilot runs in 2021-22*

**Full data taking aimed for during run 3**

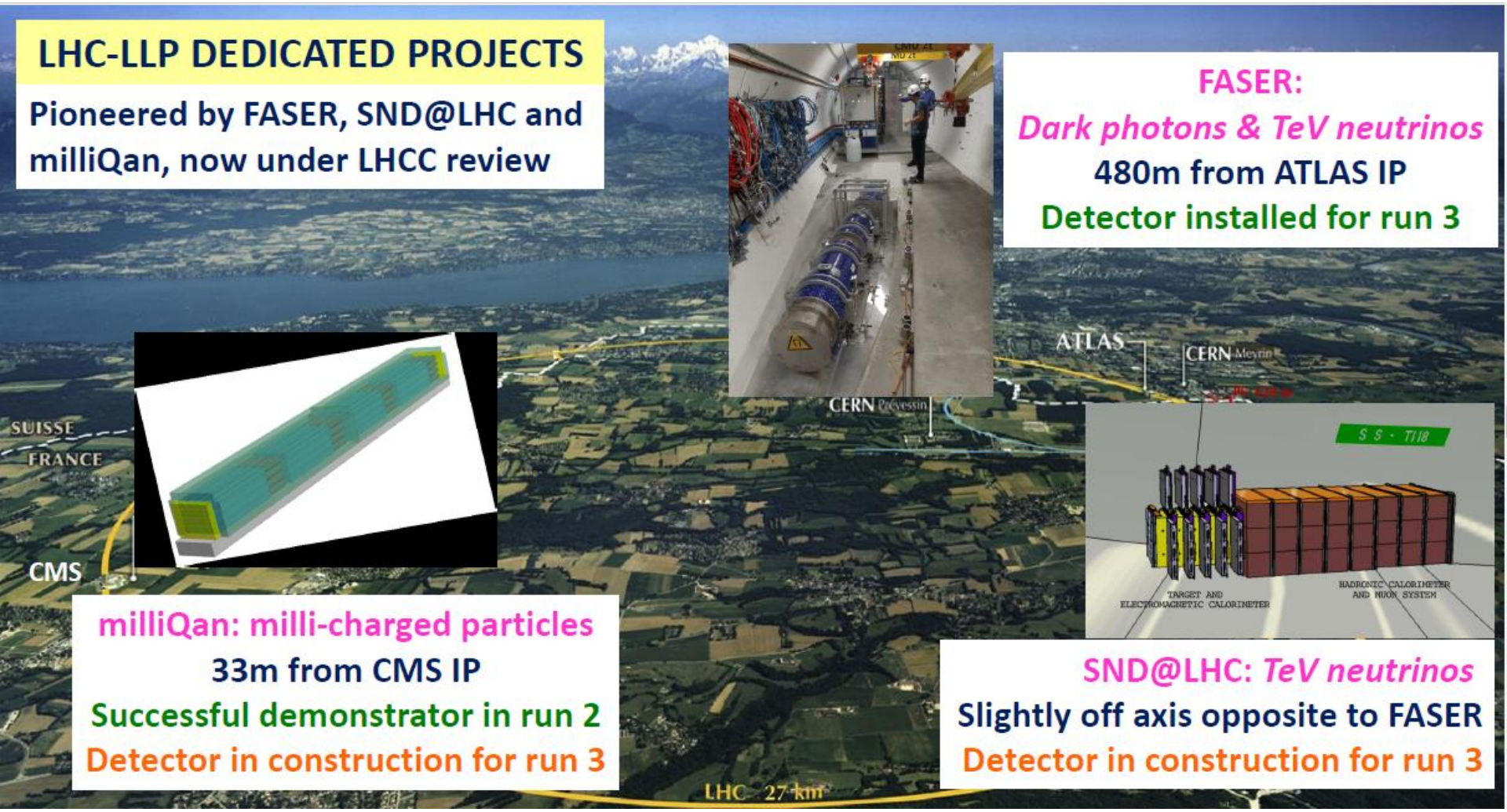



*Now in the hands of the SPSC*

# Supported projects: BSM



# Supported projects: LHC



# FPC

## The PBC past edition:
### The simplicity approach: The Portal framework

*Expand the SM with the minimal set of operators of lowest dimension gauge-invariant and renormalizable (all but the pseudo-scalar). This guarantees that the theoretical structure of the SM is preserved and any NP is just a simple extension of what we already know..*

| Portal | Coupling |
|---|---|
| Dark Photon, $A_\mu$ | $-\frac{\epsilon}{2\cos\theta_W}F'_{\mu\nu}B^{\mu\nu}$ |
| Dark Higgs, $S$ | $(\mu S + \lambda S^2)H^\dagger H$ |
| Axion, $a$ | $\frac{a}{f_a}F_{\mu\nu}\tilde{F}^{\mu\nu}$, $\frac{a}{f_a}G_{i,\mu\nu}\tilde{G}_i^{\mu\nu}$, $\frac{\delta_\mu a}{f_a}\overline{\psi}\gamma^\mu\gamma^5\psi$ |
| Sterile Neutrino, $N$ | $y_N L H N$ |

A good starting point.

They are representative of broad classes of models.

They provided us with a common ground to compare experimental results.

## What are Feebly-Interacting Particles (FIPs)?

Very roughly:

any NP with (dimensional or dimensionless) effective coupling $<< 1$

(in the PBC we concentrate on FIPs with mass below the EW scale).

[The smallness of the couplings can be generated by an approximate symmetry almost unbroken, and/or a large mass hierarchy between particles (as data seem to suggest)]

Fully complementary to high-energy searches.

Naturally long-lived.

## FPC main driver:

Exploit and further boost the potential of PBC experiments for FIP physics, taking into account the worldwide context, recent theory progress and related results from neighboring fields (axion physics, DM direct detection, astroparticle/cosmology, active neutrino physics, ….)

# How to exploit and further boost FIP physics in PBC ?

✓ With a Steering Group (== us) that meets periodically to discuss topics of interest for the FPC.

- Each meeting will be topic-oriented but will be also the occasion for circulating/discuss news of general interest (eg: hot experimental results, new theory progress, etc.).
- Depending on the evolution of the discussion the topic-oriented effort can be continued in more focused meetings/WGs. (to be discussed with you, see later)

✓ The Steering Group is made of a balanced mixture of theorists/experimentalists expert in the field.

- Each PBC experiment related to FIPs will be represented (not today, only Stefan & Igor present).
- The Steering Group should also be able to establish connections with neighboring fields (eg: DM direct detection, astroparticle, axion community, active neutrino physics,…).

→ We have in the group representatives of these communities.

The goal is to build up a community around our activity.

# The Steering Group (== us!)

- **Martin Bauer** (Durham U., UK) theorist, main interest: axions/ultra light bosons
- **James Beacham** (Duke U., US) experimentalist, ATLAS, convener LLP@LHC WG, connection to the LHC
- **Albert De Roeck** (CERN) experimentalist, CMS, convener LLP@LHC WG, connection to LHC &US neutrino community
- **Marco Drewes** (Louvain U., B) theorist, main interest: HNLs
- **Maurizio Giannotti** (Barry U., US) theorist, main interest: FIPs in stellar evolution.
- **Gian Francesco Giudice** (CERN) head of CERN Theory department and CERN representative for EuCAPT;
- **Stefania Gori:** (California U.) theorist, Convener of the RF6 (Dark sector at high intensity) Snowmass WG;
- **Pilar Hernandez** (Valencia, ES): theorist, main field: heavy neutral leptons, but she is very broad;
- **Igor Irastorza** (Zaragoza, ES) experimentalist, IAXO spokesperson, connection to axion experiments
- **Joerg Jaeckel** (Heidelberg, D) theorist, main interest: axions. Convener of CF2 in Snowmass (wavelike DM)
- **Felix Kahlhoefer** (Aachen U., D) theorist, main interest: axions/ALPs
- **Gordan Krnjaic** (FNAL & Chicago U., US): theorist, FNAL: main interest: light DM and related models.
- **Gaia Lanfranchi** (INFN, IT): experimentalist, FIPs @ extracted beam lines
- **Jacobo Lopez-Pavon** (Valencia U., ES) theorist, main interest: HNLs
- **Jocelyn Monroe** (Royal Halloway U, London, UK) experimentalist, connection to DM direct detection community.
- **Silvia Pascoli** (Bologna U., IT) theorist, main interest: neutrinos & HNLs. APPEC deputy chair and EuCAPT.
- **Maxim Pospelov** (Minneapolis U. & Perimeter I.): theorist: wide range of FIPs
- **Joshua Ruderman** (NYU, US) theorist, main interest: astroparticle
- **Philip Schuster** (SLAC, US) theorist. Main interest: light DM and related mediators, connection to US extracted beams
- **Mikhail Shaposhnikov** (EPFL, CH) theorist: worldwide reference for HNLs.
- **Jessie Shelton** (Urbana U., US): theorist, main interest: astroparticle.
- **Yevgeni Stadnik** (Tokyo U., JP) theorist, main interest: ultra-light FIPs
- **Stefan Ulmer** (Riken, JP), experimentalist (AD), connection to ultra-low FIPs

**+ representatives of PBC experiments related to FIP physics**

# ACTIVITY (1/2)

We see the FPC activity divided in three main areas:
"Work with experiments", "Work with theorists", and "General":

## 1) Work with PBC experiments:

- Propose benchmarks;
- Discuss results from PBC experiments.
- Harmonize results one another (check that they are produced using the same assumptions)
- Collect results from non-PBC experiments related to FIP physics.
- Put results in worldwide context.
- Compile and document summary plots.
- Propose recipe to publish results in a way that can be easily re-interpreted following the fast theory progress (efficiency maps as a function of lifetime, background in bins, etc.).

# Precision- and New-Physics at ISOLDE