PHYSICS BEYOND COLLIDERS

Excerpt from the 2016 PBC mandate by CERN Management:

“Explore the opportunities offered by the CERN accelerator complex and infrastructure to address some of today’s outstanding questions in particle physics through experiments complementary to high-energy colliders and other initiatives in the world.”

Time scale: next 2 decades

PBC QCD Report: arXiv:1901.04482
PBC Accelerator Reports:
http://cds.cern.ch/collection/PBC%20Reports?ln=en

Latest status to be documented at the next PBC WG meeting
5-6 November: https://indico.cern.ch/event/827066/
THE CERN LHC INJECTOR COMPLEX

> 1000 physicists
> 20 projects
QCD PROJECTS IN WORLDWIDE LANDSCAPE

Structure Functions

Unique reach of LHC-FT with high statistics at high-\(x\) / high \(Q^2\)

QCD Phase Transition

Unique reach of LHC-FT & SPS in transition region to high-\(\mu_B\)

Quark-gluon plasma

Hadronic matter
BSM PROJECTS IN WORLDWIDE LANDSCAPE

EDM & non-accelerator projects cover the very low-mass domain

SPS beam dumps probe a specific MeV-GeV domain

Precision experiments extend reach of high-E colliders

C. Vallée, ECFA-EPS, 13 July 2019 Physics Beyond Colliders 4
PBC BENCHMARK MODELS FOR HIDDEN SECTOR

defined to cover most signatures and compare reach of projects under same assumptions

Dark Photons, Dark Matter & millicharged particles

Dark Scalars

Heavy Neutral Leptons

Axion-Like Particles
## EXPERIMENTS READINESS

Summarized in a semi-quantitative table

<table>
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<tr>
<th>Project</th>
<th>Physics highlight</th>
<th>Beam requirement</th>
<th>Detector maturity</th>
<th>Collaboration</th>
<th>Cost beam+det</th>
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New projects also constrained by existing beamlines/halls/experiments
No strategic issue → now under review by SPSC & LHCC

Among potential highlights:

- Improved $(g-2)_\mu$ prediction by MUonE and contribution to $R_p$ puzzle by COMPASS
- Extension of LHCb Fixed Target capabilities
- Exploration of new dark sector domains by NA64++ and NA62 Beam Dump
LONG TERM PROJECTS

Require EPPSU guidelines to proceed

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< 10 M€ | 10-50 M€ | > 50 M€ | Run 3 | Run 4 | Run 5

C. Vallée, ECFA-EPS, 13 July 2019
Important milestone reached within PBC with successful acceleration and storage of Partially Stripped Ions in LHC

Proof of Principle experiment with full configuration foreseen at SPS after LS2

Goal of $10^7$ intensity gain versus existing facilities

NB: physics reach to be quantified once all ingredients are better understood
LHC-HOSTED PROJECTS cont’d: FIXED TARGET

“Simple” storage cells already open unique opportunities in both hadron and QGP physics

Optimization of FT- and collider-operation required to maximize LHC-FT physics reach

Already started by LHCb in run 2 with SMOG. Promising SMOG2 storage cell development:
FT lumi x ~100 in run 3

ALICE also interested
R&D ongoing on polarized gas targets and double-crystal set-ups
COMPASS++/AMBER “QCD FACILITY”

Competition from growing number of QCD facilities worldwide

Some highlights identified by PBC

With existing beams:
Unique opportunity for higher precision pion structure measurements

With new RF-separated K-beam:
(significant investment possible for post-LS3):
Comprehensive measurement of strange spectroscopy

Physics reach to be quantified as function of RF-separated beam performance
ULTRA-RARE KAON DECAYS: NA62 ($K^+$) ↔ KLEVER ($K^0$)

$K^+$ and $K^0$ have complementary sensitivity to BSM models

Phasing of KLEVER in NA62 hall is a multi-parameter issue: $K^+$ results $\leftrightarrow$ $K^+/K^0$ sensitivity $\leftrightarrow$ B-anomalies $\leftrightarrow$ KOTO

Strong improvement of KOTO performance expected in the coming decade... and possibly later.
**BEAM DUMP FACILITY:**

Comprehensive Design Study done
Conceptual Design Report foreseen for end of EPPSU

**SHiP:**

Dual spectrometer

Emulsion spectrometer for DM scattering + $\nu_\tau$ physics
**BDF/SHiP/TauFV**

**BEAM DUMP FACILITY:**

Comprehensive Design Study done

Conceptual Design Report foreseen for end of EPPSU

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**SHiP:**

Dual spectrometer

**TauFV:**

“LHCb-like” detector

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**A small upstream exp. hall could trigger a unique rare decay facility**
**BEAM DUMP FACILITY:**

Comprehensive Design Study done

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**SHiP:**

Dual spectrometer

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**TauFV:**

“LHCb-like” detector

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A small upstream exp. hall could trigger a unique rare decay facility

---

Project mature for an implementation decision pending EPPSU guidelines
SENSITIVITIES TO DARK FERMIONS (HNL’s)

- Unique short term opportunities with NA62 Beam Dump and FASER
- SHiP has the highest reach on the long term
**NEW e-BEAM: eSPS**

3.5 GeV e-LINAC with CLIC technology connected to SPS for acceleration up to 16 GeV

Slow extraction of up to $\sim 10^{16}$ e/year if 1/3 of SPS duty cycle reserved to project

Would allow hidden sector searches in the invisible mode with a LDMX-like detector
NEW e-Beam: AWAKE++

electron acceleration with a plasma cell excited by proton bunches

First accelerated e seen in 2018 (~2 GeV) - Phase 2 (~10 GeV) in preparation for run3

Could provide $\sim 10^{15}$ ~50 GeV pulsed e’s/year in the post-LS3 era for $e^+e^-$ visible searches by an experiment located in the CNGS decay tunnel

C. Vallée, ECFA-EPS, 13 July 2019
SENSITIVITIES TO DARK PHOTONS

- A significant part of the LDMX potential can be covered at SLAC (in discussion with DOE)
- AWAKE++ domain expected to be covered by the competition in the coming decade
- NA64++ has a unique short term potential
- SHiP has the highest long term potential at high mass / low couplings
EXPLORATORY STUDY OF HIGHER-ENERGY BEAMDUMPS POTENTIAL  
the example of ALPS

PBC projects have a similar reach as for visible $A'$  
(similar signatures $\gamma\gamma$ and $e^+e^-$)

No real breakthrough of  
LHC/FCC beamdumps:  
SPS seems to offer a quite optimal  
energy-intensity mix in the present context

arXiv:1902.04878
Comparison of SPS FT and HIGH-ENERGY COLLIDERS for hidden searches

*(courtesy Gaia Lanfranchi)*

Different domains of similar “sizes” explored by the various facilities

→ all approaches needed to cover the full landscape
PBC PROJECTS POSSIBLY IMPLEMENTED OUTSIDE CERN

**IAXO (axion helioscope)**
Baby-IAXO proposal submitted to DESY positively reviewed by PRC
A project with good momentum now, benefits much from CERN support

**Proton EDM RING**
CPEDM Collaboration built within PBC
Investigations revealed need for a prototype ring to test and finalize control of systematics.
Possible prototype site: COSY in Jülich

**REDTOP (rare η decays)**
* CERN beams not optimal to provide the required conditions and luminosities
  + Detector still requires significant R&D
→ suggests that an implementation at FNAL, as initially foreseen, would be more efficient.
THE MAIN PBC MESSAGES TO THE EPPSU

FOR CERN PROJECTS

LHC Fixed-Target opens a worldwide unique domain to both SF and QGP measurements

*Requires support for full exploitation of its potential on the LHC lifetime*

A SPS Beam Dump Facility would cover a worldwide unique domain for hidden sector searches complementary to high-energy colliders and non-accelerator experiments

*A mid-size project now mature for an implementation decision*

FOR PROJECTS OUTSIDE CERN

Support is required to fully exploit the potential of National Labs for both non-accelerator projects (e.g. IAXO) and precision physics (e.g. pEDM R&D)

The particle physics potential of the new European facilities such as ESS and DESY XFEL requires support to be fully exploited in the long term.
EXTRA SLIDES
PBC KICK-OFF WORKSHOP, CERN, September 2016
Call for abstracts → 20 selected for presentation

1st GENERAL WORKING GROUP MEETING, CERN, March 2017
Identification of main issues to be studied

2nd PBC WORKSHOP, CERN, November 2017
Working groups project reports
New call for abstracts → 7 selected for presentation

2nd GENERAL WORKING GROUP MEETING, CERN, June 2018
Status of studies for PBC deliverables

3rd PBC WORKSHOP: CERN, January 16-17, 2019
Summary of inputs to EPPSU and survey of future studies

3rd GENERAL WORKING GROUP MEETING, CERN, 5-6 November 2019
https://indico.cern.ch/event/827066/
Updated status of projects before EPPSU drafting session
PBC WORKING GROUP STRUCTURE

Main coordinators: J. Jaeckel, M. Lamont, C. Vallée

BSM conveners: C. Burrage, G. Lanfranchi, S. Rozanov, G. Ruoso
+ ext. experts + projects representatives:
NA62++, KLEVER, NA64++, SHiP, LDMX, IAXO, JURA, EDM

QCD conveners: M. Diehl, J. Pawlowski, G. Schnell
+ ext. experts + projects representatives:
COMPASS++, MUonE, DIRAC++, AFTER, CRYSTAL, LHCb-FT, ALICE-FT
NA61++, NA60++

~100 core members in the Working Groups
> 200 WG meetings in the past 3 years

Organisation and follow-up of activities documented on http://pbc.web.cern.ch/
### PBC DELIVERABLES: ACCELERATOR WGs

<table>
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<tr>
<th>Working group</th>
<th>10 pager for ESPP for 18th December - WG dependent</th>
<th>Possible proponents/clients submitting 10 pager to ESPP</th>
<th>PBC deliverable for 18th December * (referenced by 10 pager)</th>
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<tr>
<td>AWAKE++</td>
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<td>Proposed client experiment</td>
<td>Exploratory study</td>
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<tr>
<td>BDF</td>
<td>Y</td>
<td>SHiP, tauFV</td>
<td>Comprehensive Design Study - tauFV as appendix</td>
</tr>
<tr>
<td>Conventional beams</td>
<td>Y</td>
<td>NA61, NA62++, KLEVER etc.</td>
<td>Description of the conventional beam upgrades associated to the proposed projects</td>
</tr>
<tr>
<td>EDM</td>
<td>Y</td>
<td></td>
<td>3 appendices: COSY; prototype; full ring (feasibility study).</td>
</tr>
<tr>
<td>eSPS</td>
<td>Y</td>
<td>LDMX,BD</td>
<td>Technical report on possible implementation at CERN</td>
</tr>
<tr>
<td>FASER acc.</td>
<td>N</td>
<td>FASER</td>
<td>Technical report on possible implementation in LHC</td>
</tr>
<tr>
<td>Gamma factory</td>
<td>Y</td>
<td></td>
<td>Exploratory study</td>
</tr>
<tr>
<td>LHC FT</td>
<td>N</td>
<td>AFTER@LHC, LHCspin, MDM/EDM</td>
<td>Technical study of feasibility</td>
</tr>
<tr>
<td>nuSTORM</td>
<td>Y</td>
<td></td>
<td>Broad outline of a possible nuSTORM implementation at CERN</td>
</tr>
<tr>
<td>Perf post-LIU</td>
<td>N</td>
<td></td>
<td>Injector complex performance after LIU</td>
</tr>
<tr>
<td>Technology</td>
<td>Y</td>
<td>IAXO et al</td>
<td>Exploration and evaluation of possible technological contributions of CERN to non-accelerator projects possibly hosted elsewhere</td>
</tr>
</tbody>
</table>

IMPLEMENTATION CONSTRAINTS OF NEW PROJECTS

Governed to a great extent by existing beamlines/halls/experiments

e.g. SPS North Area:

**EHN1**
general purpose hall with unique high-E / medium-I beams for all particles

**ECN3**
unique underground hall for high-I hadron beams

**EHN2**
unique high-E / high-I μ-beam
Neutron EDM is leading the field for hadrons
Catching up in precision is a challenge for the proton
**MAIN CURRENT BEAM DUMP PROJECTS OUTSIDE CERN**

<table>
<thead>
<tr>
<th>EXPERIMENT</th>
<th>PERIOD</th>
<th>BEAM</th>
<th>PARTICLES ON TARGET</th>
<th>SIGNATURE</th>
<th>MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPS @JLAB</td>
<td>2016-20</td>
<td>e 2-6 GeV</td>
<td>~10^{20}</td>
<td>visible e^+e^-</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>APEX @JLAB</td>
<td>2018-19</td>
<td>e 1-4.5 GeV</td>
<td>~10^{20}</td>
<td>visible e^+e^-</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>BDX @JLAB</td>
<td>~2022</td>
<td>e 12 GeV</td>
<td>~10^{22}</td>
<td>recoil e</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>LDMX @SLAC</td>
<td>&gt; 2022</td>
<td>e 4-8 GeV</td>
<td>2 10^{16}</td>
<td>invisible</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>MiniBooNe @FNAL</td>
<td>2013-14</td>
<td>p 8 GeV</td>
<td>1.8 10^{20}</td>
<td>recoil e, N</td>
<td>DP</td>
</tr>
<tr>
<td>SBND @FNAL</td>
<td>&gt;2020</td>
<td>p 8 GeV</td>
<td>6 10^{20}</td>
<td>recoil Ar</td>
<td>DP</td>
</tr>
<tr>
<td>SEAQUEST @FNAL</td>
<td>2021-30</td>
<td>p 120 GeV</td>
<td>10^{18} → 10^{20}</td>
<td>visible e^+e^-</td>
<td>DP, DS, HNL</td>
</tr>
<tr>
<td>LBND @FNAL</td>
<td>&gt;2025</td>
<td>p 120 GeV</td>
<td>~10^{21}</td>
<td>recoil e, N</td>
<td>DP, DS, HNL</td>
</tr>
</tbody>
</table>

Recent dedicated experiments demonstrate a regain of interest for beam dumps. Flavour factories (BELLE II, ...) have also some sensitivity from exotic decays.

DP = Dark Photon  
DS = Dark Scalar  
HNL = Heavy Neutral Lepton  
ALP = Axion-Like Particle
## BEAM DUMP PROJECTS AT CERN

<table>
<thead>
<tr>
<th>EXPERIMENT</th>
<th>PERIOD</th>
<th>BEAM</th>
<th>PARTICLES ON TARGET</th>
<th>SIGNATURE</th>
<th>MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA64++(e)</td>
<td>2015-24</td>
<td>e 100 GeV</td>
<td>(\sim 5 \times 10^{12})</td>
<td>invisible &amp; visible (e^+e^-)</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>eSPS/LDMX</td>
<td>&gt; 2026</td>
<td>e 16 GeV</td>
<td>(10^{16})</td>
<td>invisible</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>AWAKE++</td>
<td>&gt; 2026</td>
<td>e (\sim 50) GeV</td>
<td>(\sim 10^{15})</td>
<td>visible (e^+e^-)</td>
<td>DP, ALPs</td>
</tr>
<tr>
<td>NA62++</td>
<td>&gt; 2022</td>
<td>p 400 GeV</td>
<td>(10^{18})</td>
<td>visible</td>
<td>DP, DS, HNL, ALPs</td>
</tr>
<tr>
<td>SHiP</td>
<td>&gt; 2026</td>
<td>p 400 GeV</td>
<td>(2 \times 10^{20})</td>
<td>recoil &amp; visible</td>
<td>DP, DS, HNL, ALPs</td>
</tr>
<tr>
<td>NA64++((\mu))</td>
<td>&gt; 2022</td>
<td>(\mu) 160 GeV</td>
<td>(5 \times 10^{13})</td>
<td>invisible</td>
<td>(DZ_{\mu}), ALPs</td>
</tr>
</tbody>
</table>

**NB: CERN offers unique opportunities with both lepton and hadron beams**

LHCb and LHC-LLP dedicated projects (FASER, milliQan, CODEX-b, MATHUSLA) have also sensitivity in similar mass range

DP = Dark Photon  
DS = Dark Scalar  
HNL = Heavy Neutral Lepton  
ALP = Axion-Like Particle
## LEVEL OF MATURITY OF SENSITIVITY ESTIMATIONS

<table>
<thead>
<tr>
<th>Project</th>
<th>Background</th>
<th>Efficiency</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA62++</td>
<td>0-BG assumed</td>
<td>partly included</td>
<td>$10^{16}$ PoT run in BD mode</td>
</tr>
<tr>
<td>KLEVER</td>
<td>partly included</td>
<td>included</td>
<td>fast simulation</td>
</tr>
<tr>
<td>REDTOP</td>
<td>included</td>
<td>included</td>
<td>full simulation</td>
</tr>
<tr>
<td>NA64++(e)</td>
<td>included</td>
<td>included</td>
<td>real data</td>
</tr>
<tr>
<td>NA64++(\mu)</td>
<td>0-BG assumed</td>
<td>100 % assumed</td>
<td>M2 $\mu$ beamtest</td>
</tr>
<tr>
<td>eSPS/LDMX</td>
<td>included</td>
<td>included</td>
<td>full simulation at 4 GeV</td>
</tr>
<tr>
<td>AWAKE++</td>
<td>0-BG assumed</td>
<td>100 % assumed</td>
<td>toy model</td>
</tr>
<tr>
<td>SHiP</td>
<td>0-BG assumed</td>
<td>included</td>
<td>full simulation</td>
</tr>
<tr>
<td>CODEX-b</td>
<td>0-BG assumed</td>
<td>included</td>
<td>full simulation</td>
</tr>
<tr>
<td>FASER</td>
<td>0-BG assumed</td>
<td>100 % assumed</td>
<td>BG simulations &amp; in situ measurements</td>
</tr>
<tr>
<td>MATHUSLA200</td>
<td>0-BG assumed</td>
<td>100 % assumed</td>
<td>cosmic &amp; LHC BG fluxes</td>
</tr>
<tr>
<td>milliQan</td>
<td>included</td>
<td>included</td>
<td>full simulation</td>
</tr>
</tbody>
</table>
**Beam Dumps Experimental Methods**

**Visible decay to SM particles**

\[ \text{signal} \propto \varepsilon^4 \]

Critical: BG control

**Recoil e/N from rescattering**

\[ \text{signal} \propto \varepsilon^4 \]

Critical: BG control

**Missing energy from invisible decays**

\[ \text{signal} \propto \varepsilon^2 \]

Critical: initial particle and pileup control

**NB: reach in \((m, \varepsilon)\) depends on many parameters:**

beam energy & intensity, decay length, signatures, background ...

---

C. Vallée, ECFA-EPS, 13 July 2019 Physics Beyond Colliders
HIDDEN SECTOR MAIN PRODUCTION MODES

Primakov/Bremstrahlung:
Mass reach mainly in sub-GeV domain, weakly dependent on beam energy

Meson decays:
Mass reach in multi-GeV domain dependent on accessible meson mass thresholds (K,D,B)

EXPERIMENTAL SIGNATURES

<table>
<thead>
<tr>
<th>Models</th>
<th>Final states</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNL, SUSY neutralino</td>
<td>$l^+\pi^-, l^+K^-, l^+\rho^- \rho^+\rightarrow \pi^+\pi^0$</td>
</tr>
<tr>
<td>Vector, scalar, axion portals, SUSY sgoldstino</td>
<td>$l^+l^-$</td>
</tr>
<tr>
<td>HNL, SUSY neutralino, axino</td>
<td>$l^+l^-\nu$</td>
</tr>
<tr>
<td>Axion portal, SUSY sgoldstino</td>
<td>$\gamma\gamma$</td>
</tr>
</tbody>
</table>

+ recoil particles or missing energy for rescattering / missing energy methods
"Cheap" setup implemented in 2015 on H4 e test beam

Wish also to extend the method to μ / hadron beams:
- Few months of μ beam would test a \((g-2)_{\mu}\) interpretation
- Few years of μ beam would improve limits on millicharged particles

Main issue: competition with COMPASS on μ beam

Higher intensities foreseen after LS2
Main issue: DAQ capabilities and pileup control
Reminder: main NA62 goal is ultra-rare decay $K^+ \rightarrow \pi^+ \nu \nu$

Successful data taking since 2016, more needed after LS2 to reach goal of ~100 events

Some data taking in beam dump mode under consideration during run 3
Achieved by closing the TAX collimator
1 year would correspond to $\sim 10^{18}$ PoT

Instrumentation of NA62 decay vessel well adapted to searches in visible mode
KLEVER: $K^0 \rightarrow \pi^0\nu\bar{\nu}$ rare decay

$K^0$ decays complementary to $K^+$ decays for the CKM matrix and BSM searches.

*Would require a new high intensity $K^0$ beam.*

~50 events could be collected with a similar but basically new detector.

**Competition from starting KOTO at JPARC:**

few events expected in coming years, upgrade by factor $\sim 10$ foreseen $> 2025$

---

**Main issues:** actual sensitivity vs competition, cost of new beam and upgraded detector
Interception of small BDF beam fraction to look for $\tau \rightarrow 3\mu$ decays

Could set limits on branching ratio better than $10^{-10}$ level (~BELLE-II reach)

Implementation layout upstream of BDF target under study

A promising option to maximize the physics reach of the Beam Dump Facility
Main issues:

• 2 GeV continuous proton beam (PS best option but non-nominal for REDTOP)
• Demanding detector technology (Optical TPC and dual readout calorimetry)

It is a Goldstone boson

Symmetry constrains its QCD dynamics

It is an eigenstate of the C, P, CP and G operators (very rare in nature): \( J^{PC} = 0^+ 0^- \)

It can be used to test C and CP invariance.

All its additive quantum numbers are zero (very clean state)

\[ Q = I = j = S = B = L = 0 \]

Its decays are not influenced by a change of flavor (as in K decays) and violations are “pure”

All its possible strong decays are forbidden in the lowest order by P and CP invariance, G-parity conservation and isospin and charge symmetry invariance.

It is a very narrow state (\( \Gamma_\eta = 1.3 \text{ KeV} \) vs \( \Gamma_p = 149 \text{ MeV} \))

Contributions from higher orders are enhanced by a factor of \(~100,000\)

Excellent for testing invariances

EM decays are forbidden in lowest order by C invariance and angular momentum conservation
Opportunity to study open charm close to expected CP-region.
Was not done by 1st generation SPS QGP-experiments.

Also unique measurements for ν-beams and cosmics rays.

Moderate detector upgrades required, well under control in collaboration with ALICE.

Unique physics reach
No new competition on beamline.
NA60++ and DIRAC++

Unique physics reach for both

High hadron beam intensities

→ only reasonable implementation is in ECN3

Both beams could fit together in ECN3

But implementation can be done only once NA62 has freed the hall
(g-2)$_\mu$ uncertainties

MUonE ↔ COMPASS($R_p$)

\[ \mu^- + e^- \leftrightarrow \mu^- + p^- \]

elastic scattering

In competition on same $\mu$-beam in EHN2

Suitable MUonE position identified upstream of COMPASS

new COMPASS TPC


Convincing physics motivation

Both projects still need better quantification of feasibility and precision

Studies for common siting and/or operation to be strengthened
DARK VECTORS IN DM PARAMETER SPACE (BC2)

\[ \alpha_D = 0.1 \quad m_\chi = \frac{1}{3} m_{A'} \]
Dark Photon invisible mode

- Unique NA64++(e) short term opportunity to explore the relevant DM parameter space
- Significantly higher reach of LDMX@eSPS, to be put in regard with a possible faster&cheaper implementation of LDMX at SLAC (pending approval of LCLS-II beam extraction)

\[ \alpha_D = 0.1 \]
\[ m_\chi = \frac{1}{3} m_{\alpha'} \]
DARK SCALARS

BC4

BC5

C. Vallée, ECFA-EPS, 13 July 2019
Physics Beyond Colliders
ALPS IN BEAMDUMPS

BC9

BC10

BC11
Unique sensitivity to low-mass ALPs

(Baby)IAXO (helioscope successor of CAST) supported by CERN for magnet design
DESY considered as candidate site

JURA possible long term LSW experiment combining state-of-the-art ALPS II optics and high-field CERN magnets
MilliQan, MATHUSLA, FASER, Codex-b @ the LHC IPs

LHC-LLP DEDICATED PROJECTS

Phase I recently approved for run 3

NB: all “small scale” projects except MATHUSLA
PROTOTYPING OF NEW FACILITIES: EDM RING

Design sensitivity: 4x10^{-29} e-cm
Requires:
-- electrostatic deflector 8MV/m
-- magnetic shielding
-- high precision SQUID BPMs to monitor the total radial magnetic field by vertical beam position separation between CW/CCW

Full ring
~160 m Ø

Prototype ring
~30 m Ø

CPEDM Collaboration built within PBC

Investigations revealed need of a prototype ring to test and finalize control of systematics. Possible prototype site: COSY in Jülich
Well controlled $\nu$ beam from a $\mu$ storage ring

Precise $\sigma(\nu)$ measurements and a path towards a $\nu$ factory or a $\mu$ collider.
4 running experiments devoted to Antiproton and Antihydrogen Properties

2.5 more in preparation to test gravity of Antihydrogen: AEGIS/GBAR/ALPHA-g

AFTER LS2: ELENA

Further deceleration of pbar from 5 MeV to 100 KeV → trapping efficiency x ~100

Secures antimatter physics for the next decade