Beyond Colliders

Mike Lamont
Joerg Jaeckel, Claude Vallée
PBC working groups
PBC - Brief

• Maximize physics reach of existing complex
  – New facilities exploiting existing complex
  – Novel exploitation of existing facilities
  – Provide support for novel off-site facilities
  – Harness the existing expertise and resources

Within the limits posed by an already vibrant and diverse physics program (beam, resources)

Evaluate these options motivation and competitiveness in a world wide scape
PBC accelerator side - main themes

- Exploitation of SPS/North Area
  - Conventional North Area beams, BDF for SHiP/TauFV, eSPS, nuSTORM
- Novel approaches
  - EDM storage ring, Gamma Factory, AWAKE++
- LHC
  - LHC fixed target (gas, crystals), Long Lived Particles
- Technology
  - Leveraging CERN’s technical expertise - various options (IAOX, LSW, VMB...)
NA64++ (electrons)  
H4: 100 GeV  
up to 5e12 eot/year

North Area

BDF -> SHiP, TauFV  
400 GeV protons  
4e19 pot/year

NA64++ (muons)  
M2: 100 – 160 GeV  
up to 1e13 mot/year

NA62-dump mode  
K12: 400 GeV protons  
up to 1e19 pot/year

KLEVER  
K12: 400 GeV protons  
up to 1e19 pot/year

Attempting to rebrand as the HSC (Hidden Sector Campus)
## Conventional Beams at the North Area

Proposals followed by the CB WG - healthy mix of HS/QCD

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Sector</th>
<th>Proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA62++</td>
<td>Dark Sector</td>
<td>Optimise conditions for NA62 in beam dump mode</td>
</tr>
<tr>
<td>NA64++ (e,h)</td>
<td>Dark Sector</td>
<td>Increase electron flux and optimise hadron beams in the H4 line</td>
</tr>
<tr>
<td>NA64++ (u)</td>
<td>Dark Sector</td>
<td>Study a NA64-like experiment with muons in EHN2</td>
</tr>
<tr>
<td>KLEVER</td>
<td></td>
<td>$K_0 \rightarrow \pi^0 \nu \bar{\nu}$ New beam for a rare decays with high proton flux</td>
</tr>
<tr>
<td>NA61++</td>
<td>QGP charm</td>
<td>Higher intensity with better protection</td>
</tr>
<tr>
<td>COMPASS++</td>
<td>Full QCD program</td>
<td>Study new requests from COMPASS, including a RF separated beam</td>
</tr>
<tr>
<td>MUonE</td>
<td>HVP (g-2)</td>
<td>Implementation for operation with $\mu$ and $e$ beams</td>
</tr>
<tr>
<td>DIRAC++</td>
<td>Chiral QCD</td>
<td>Options for a DIRAC follow-up experiment at the SPS</td>
</tr>
<tr>
<td>NA60++</td>
<td>QGP phase</td>
<td>Options for a NA60 follow-up experiment with heavy ion beams</td>
</tr>
</tbody>
</table>

• Maturity of proposals and the effort required varies considerably
• Follow-up dictated by collaboration strength and CERN side resources; overseen by CERN committees
SPS Beam Dump Facility (BDF)

- Slow extraction from SPS into existing TT20 transfer line
- Switch to new transfer line at existing North Area splitters
- Heavy target plus hadron absorber
- Target complex with sophisticated handling capabilities
- Underground Experimental Hall

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Momentum</td>
<td>400 GeV/c</td>
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<tr>
<td>Beam intensity on target per cycle</td>
<td>4.0e13</td>
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<tr>
<td>Cycle length</td>
<td>7.2 s</td>
</tr>
<tr>
<td>Spill duration</td>
<td>1 s</td>
</tr>
<tr>
<td>Avg. power on target</td>
<td>355 kW</td>
</tr>
<tr>
<td>Avg. power on target during spill</td>
<td>2560 kW</td>
</tr>
<tr>
<td>Protons on target (PoT) per year</td>
<td>4e19</td>
</tr>
<tr>
<td>PoT in 5 years’ data taking</td>
<td>2.0e20</td>
</tr>
</tbody>
</table>
BDF Study

• 2016-2018: **3 year feasibility study** following work since EOI 2013
  – extraction, beamlines, target, target complex, experimental hall, integration, civil engineering, safety, and radiation protection

• BDF Comprehensive Design Study in pre-publication
BDF Study

- Feasibility confirmed:
  - factor 3 reduction in SPS slow extraction losses demonstrated – confident to reach required x4
  - transfer line and dilution – well within CERN’s established capabilities
  - target – challenging – extensive studies – prototype built and tested with beam
  - fully developed target complex study in collaboration with external company
  - phase 1 civil engineering and integration studies completed
  - RP studies showed the general feasibility in terms of radiation/radiological impact on the environment
**BDF - Summary**

- **The study is mature.**
- Operationally it will be challenging but no show stoppers were identified.
- **Possible time-line:**
  - continued design studies and prototyping
  - ~3 years for TDR, followed by preparation for construction, component production
  - Construction of BDF ~5 years
    - Civil engineering for junction cavern/first part of new transfer line during LS3 (North Area stop)
    - Operation in Run 4
- **Material cost:** ~160 MCHF (class 4 estimate)
 TauFV

Search for Lepton Flavour Violation and rare decays

Using a thin in-line target to intercept about 2% of the intensity delivered to the SHiP target

Would have access to close to $8 \times 10^{13}$ tau lepton and $5 \times 10^{15}$ $D_0$ meson decays

Proposal under development (appendix in BDF CDS)
eSPS

- ~70 m long X-band based linac (CLIC technology) in TT4-5 accelerates e- to 3.5 GeV
- SPS filled in 1 to 2 s via TT60
- Acceleration to 16 GeV in the SPS
- Slow resonant extraction down the TT10 transfer line in ~10 s
- Beam delivered via the existing TT10 line to the Meyrin site
- A new, short beamline would branch from TT10 to the experimental hall (LDMX)
eSPS: Feasibility

• Feasibility – following initial study looks good
  – Additional RF in SPS to be studied (old LEP or FCC-ee cavities)
• Maximal use of existing structures, small foot print, and thus relatively inexpensive.
• SPS cycle sharing implications
  – ~12 s cycle, 10 s slow extraction giving 1e8 – 1e9 EOT/s
• Material cost: ~80 MCHF

Well developed proposal:
“Dark Sector Physics with a Primary Electron Beam Facility at CERN”
presented as EoI to SPSC
eSPS: Motivation

- **Electrons back in the complex** – good given CERN’s apparent long term options
- **Staged deployment of X-band** – return on the significant investment
- Possible deployment of **FCC-ee RF cavities and high-efficiency power generation**
- Strong case made for **accelerator based R&D** and other studies at the linac R&D facility
- Physics case - **unique LDM search reach**

**Preparing for future** – staged deployment of FCC-ee/CLIC technology while preparing the long term strategic vision; at the same time performing a competitive LDM search - a game changer in the case of positive result and naturally important input to future plans.
nuSTORM

• Well developed proposal for possible siting at FNAL circa 2013
• Siting at CERN – exploratory study:
  – Via existing fast extraction system at SPS point 6 into a new transfer line
  – Graphite target, magnetic horn
  – Target complex design based exploits extensive work done for CENF
  – Containment and transport of pion beam
  – New design for decay ring (SC FFA):
    • Central momentum between 1 GeV/c and 6 GeV/c;
    • Momentum acceptance of up to ±16%
nuSTORM

- Fast extraction, transfer, target/horn within CERN’s established expertise
- Potential green field site with appropriate geology
- Study in early stages. Muon storage ring is certainly challenging.
**Potential major SPS/North Area users**

<table>
<thead>
<tr>
<th></th>
<th>Momentum GeV/c</th>
<th>Int/Cycle</th>
<th>Flat top length</th>
<th>POT/year</th>
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</thead>
<tbody>
<tr>
<td>NA CB</td>
<td>400</td>
<td>2 – 4.9e13</td>
<td>4.8</td>
<td>~1e19</td>
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<tr>
<td>SHiP</td>
<td>400</td>
<td>4e13</td>
<td>1.2</td>
<td>4e19</td>
</tr>
<tr>
<td>KLEVER</td>
<td>400</td>
<td>~2e13</td>
<td>4.8</td>
<td>1e19</td>
</tr>
<tr>
<td>ENUBET</td>
<td>400</td>
<td>4.5e13</td>
<td>4.8</td>
<td>5.2e19</td>
</tr>
<tr>
<td>nuSTORM</td>
<td>100</td>
<td>4e13</td>
<td>1.0</td>
<td>4e19</td>
</tr>
<tr>
<td>eSPS</td>
<td>16</td>
<td>~3.1e11</td>
<td>10.0</td>
<td>1e18 EOT</td>
</tr>
</tbody>
</table>

- **Standard NA operations compatible with BDF for SHiP/TauFV**
- **KLEVER in parallel would be possible – with some penalties**
- **Another major user (eSPS, nuSTORM, ENUBET) would imply compromise or temporal separation**

![SPS availability: 80%](image)

**Preliminary**
EDM Storage Ring

• Principles of **all electric proton storage ring with frozen spin at “magic momentum”** well established
• Interesting potential statistical sensitivity ($\sim 10^{-29}$ e.cm)
• **Challenging systematics**
  – in particular parasitic radial magnetic field ($\sim 10$ aT mimics $10^{-29}$ e.cm)
• **Extensive studies by EDM community:**
  – Polarimetry, deflectors, magnetic shielding, instrumentation
  – Optics, lattice, ring design, beam dynamics
  – Systematics and proposed mitigation measures, simulations

EDM rotates spin in E-field

$$\frac{d\vec{s}}{dt} = \vec{d} \times \vec{E}$$

EDM rotation detected here
PROTOTYPE SEEN AS ESSENTIAL NEXT STEP

- Small (100 m circum.) designed to operate 2 modes: all-electric at 30 MeV; and combined electric and magnetic fields to allow frozen spin operation at 45 MeV.
- Lattice design will mimic that of the full ring in order to test as many features as possible on a smaller scale.
- If the prototype is at COSY, takes advantage of the existing facility for the production of polarized proton (and deuteron) beams, beam bunching, and spin manipulation.

Yellow report in pre-publication – includes preliminary design of prototype
LHC accelerates its first "atoms"

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

#36db60ae5cb4
https://interestingengineering.com/cerns-large-hadron-collider-accelerates-its-first-atoms
https://www.sciencenews.org/article/physicists-accelerate-atoms-large-hadron-collider-first-time
https://www.maxisciences.com/lhc/le-grand-collisionneur-de-hadrons-lhc-accomplit-une-grande-premiere_art41268.html
https://www.symmetrymagazine.org/article/lhc-accelerates-its-first-atoms
Gamma factory

• Accelerate and store high energy beams of highly ionised atoms and excite their atomic degrees of freedom by laser photons to produce:

**primary beams:**
- partially stripped ions
- electron beam (for LHC)
- gamma rays

**secondary beam sources:**
- polarised electrons,
- polarised positrons
- polarised muons
- neutrinos
- neutrons
- vector mesons
- radioactive nuclei

**collider schemes:**

\[ \gamma \gamma \text{ collisions, } E_{CM} = 0.1 \text{ -- } 800 \text{ MeV} \]

\[ \gamma \gamma_L \text{ collisions, } E_{CM} = 1 \text{ -- } 100 \text{ keV} \]

\[ \gamma \text{--} p(A), \text{ep}(A) \text{ collisions, } E_{CM} = 4 \text{ -- } 200 \text{ GeV} \]
Gamma Factory project milestones

1. **Production, acceleration and storage** of “atomic beams” at CERN accelerator complex.

2. **Proof-of-Principle (PoP)** experiment in the SPS tunnel.

3. **Development “ab nihilo”** the requisite Gamma Factory **software tools**.

4. **Realistic assessment** of Gamma Factory **performance figures**.

5. **Physics highlights** of Gamma Factory based **research programme**.

6. Gamma Factory **TDR**.

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*Early stages of a well developed program – significant potential*
Next step: Proof of principle in SPS

Mechanical frame of F-P cavity

Fabry-Perot cavity layout

Laser system

Letter of Intent to SPSC incoming
### Exploration and evaluation of possible technological contributions of CERN to non-accelerator projects possibly hosted elsewhere:

<table>
<thead>
<tr>
<th>Technology concerned</th>
<th>Benefit from CERN</th>
<th>Benefit to CERN</th>
<th>How facilitate?</th>
<th>Exps concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet, concretely: high-field, large-bore</td>
<td>availability of strong fields, CERN expertise to build custom magnets</td>
<td>make optimal physics use of magnet resources (spares)</td>
<td>advertise magnet usage times, provide expertise in magnet design, PBC-fellow for IAXO</td>
<td>IAXO, JURA, STAX, VMB@CERN</td>
</tr>
<tr>
<td>Optics/Optics sensing, concretely: Fabry Perot, membranes</td>
<td>surface coating, possibility to combine magnet with optics</td>
<td>add local expertise on cavity optics technologies</td>
<td>“optics hub”, as described in the document</td>
<td>aKWISP, VMB@CERN, JURA</td>
</tr>
<tr>
<td>Radiofrequency cavities, concretely: design for axion searches</td>
<td>experience in design and production</td>
<td>new cavity designs for various physics purposes, tuning and characterization in cryogenic environment</td>
<td>mandate for cavity experts to aid in design</td>
<td>Grenoble initiative, &amp; other Haloscope initiatives operating already at CERN, STAX</td>
</tr>
<tr>
<td>Cryogenics, concretely: large-scale: helium, argon, krypton from 120K to mK</td>
<td>availability of cryogenic facilities</td>
<td>participate in research beyond collider</td>
<td>mandate through TECR</td>
<td>DarkSide, aKWISP, VMB@CERN, IAXO</td>
</tr>
<tr>
<td>Vacuum, concretely: large-scale leak testing</td>
<td>experience &amp; availability</td>
<td>participate in research beyond collider</td>
<td>mandate through TES</td>
<td>DarkSide, JURA, aKWISP, CNT</td>
</tr>
</tbody>
</table>

Andrzej Siemko, Babette Dobrich et al
Initiatives integrated into the Techno WG

1) Haloscope
   LNCMI-Grenoble

2) DarkSide

3) aKWISP

4) VMB@CERN

5) Helioscope
   IAXO

6) JURA (LSW combining ALPS-III and OSQRAR+)

7) LSW-STAX

8) CNT Based DM Detector
   PTOLEMY
## Technology: Summary

“In summary, albeit CERN being an accelerator lab, also non-accelerator experiments can profit from CERN expertise and bring further diversity to CERN.”

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Goal</th>
<th>Tech</th>
<th>CERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMB@CERN</td>
<td>VMB</td>
<td>Search for Vacuum Magnetic Birefringence</td>
<td>optics, magnets</td>
</tr>
<tr>
<td>JURA</td>
<td>LSW/ALPS</td>
<td>Via optics, detector development at ALPS II + FCC magnets</td>
<td>magnets</td>
</tr>
<tr>
<td>STAX</td>
<td>LSW/ALPS</td>
<td>transition-edge-sensors (TES); high Q Fabry-Perot cavities</td>
<td>magnets, cryo, RF</td>
</tr>
<tr>
<td>BabyIAXO/IAXO</td>
<td>Helioscope</td>
<td>Next generation CAST, independent collaboration</td>
<td>magnets</td>
</tr>
<tr>
<td>DarkSide</td>
<td>WIMPs</td>
<td>Independent collaboration</td>
<td>vac, cryo, SIPM</td>
</tr>
<tr>
<td>Carbon Nano Tubes</td>
<td>CNB, DM</td>
<td>Electron recoils in large arrays of parallel carbon nanotubes - DM target for PTOLEMY</td>
<td>new material studies, neutrons</td>
</tr>
<tr>
<td>aKWISP</td>
<td>Chameleons</td>
<td>short-distance interactions at sub-micron scales</td>
<td>cryo, thin films..</td>
</tr>
<tr>
<td>Optics Technology Hub</td>
<td></td>
<td>Advanced optics technologies</td>
<td>optics</td>
</tr>
</tbody>
</table>
Also considered

• **LHC fixed target**
  – Standard and polarized gaseous targets
  – Crystals: single to target; double ($\Lambda$ MDM), triple ($Ds \rightarrow \tau$)...

• **LHC LLP**
  – FASER – for installation in LS2
  – MATHUSLA, CODEX-b, milliQan considered by BSM WG

• **AWAKE++**
  – Possible use of PWFA in an electron beam dump experiment

• **REDTOP**
  – eta factory, possible at PS but POT would conflict with existing users
Physics Motivation (BSM)

- **Sub-eV**: axions, axion-like particles
- **MeV – GeV**: RH neutrinos below the EW scale, Axion-Like Particles, Light Dark Matter
- **>>TeV**: search for NP in clean and very rare flavour processes or in EDMs
The **BSM PBC projects** offer significant discovery potential over a wide range of masses and couplings.

- Very sensitive low energy experiments target the sub-eV mass area.
- SPS Fixed Target beam-dump-like experiments and long lived particle searches at LHC have unique capabilities to target the MeV-GeV domain
- The precision tests of flavor violation (lepton and quark), as well as of CP violation, probe new particles in a mass range exceeding LHC direct searches.

**in addition: QCD and others facilities**

**Rare decays and precise measurements**
- KLEVER ($K^0_L \rightarrow \pi^0\nu\nu$)
- TauFV@BDF: $\tau \rightarrow 3\mu$
- REDTOP ($\eta$ decays)
- MUonE (hadronic vacuum polarization for (g-2)_\mu)
- EDM proton storage ring

**Hidden sector with “beam dumps”**
- NA64++ (e,\mu)
- NA62++
- Beam Dump Facility at North Area (SHiP)
- LDMX@eSPS
- AWAKE++

**QCD measurements**
- COMPASS++, DIRAC++
- NA61++, NA60++
- Fixed target (gas, crystals) in ALICE & LHCb

**Long-lived particles from LHC collisions**
- FASER, MATHUSLA, CODEX-b, milliQAN

**Other facilities:**
- $\gamma$-factory from Partially Stripped Ions; nuSTORM

**Non-accelerator projects**
- Exploit CERN’s technology (RF, vacuum, magnets, optics, cryogenics) for experiments possibly located in other labs.
- E.g. axion searches: IAXO (helioscope), JURA (Light Shining through Wall)

**courtesy FG**
Conclusions

• Interesting exercise, fostered a number of options to exploit the complex and technology - mix of:
  – smaller scale options which can be addressed within CERN’s remit
  – promising novel proposals – venture capital
  – larger scale projects

• Initiatives are :
  – well motivated by their physics potential in interesting times;
  – cost-effective opportunities to make a significant contribution and provide important input to future plans;
  – allow full exploitation of the complex in parallel to the LHC and preparation for the longer term.
BACKUP
# Reports

Submission to ESPP update/recent summary as appropriate

<table>
<thead>
<tr>
<th>Document</th>
<th>Submitted by</th>
<th>Link to document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary Report of Physics Beyond Colliers at CERN</td>
<td>PBC coordination</td>
<td>CDS</td>
</tr>
<tr>
<td>Physics Beyond Colliders QCD Working Group Report</td>
<td>QCD Working Group</td>
<td>CDS</td>
</tr>
<tr>
<td>Report of the BSM Working Group of the Physics Beyond Colliders at CERN</td>
<td>BSM Working Group</td>
<td>CDS</td>
</tr>
<tr>
<td>SPS Beam Dump Facility Comprehensive Design Study</td>
<td>BDF Working Group</td>
<td>CDS (to be published)</td>
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<tr>
<td>Report from the Conventional Beams Working Group...</td>
<td>Conventional Beams Working Group</td>
<td>CDS</td>
</tr>
<tr>
<td>AWAKE++: The AWAKE Acceleration Scheme for New Particle Physics Experiments at CERN</td>
<td>AWAKE++ Working Group</td>
<td>CDS (to be published)</td>
</tr>
<tr>
<td>PBC technology subgroup report</td>
<td>Technology Working Group</td>
<td>CDS</td>
</tr>
<tr>
<td>Dark Sector Physics with a Primary Electron Beam Facility at CERN</td>
<td>eSPS</td>
<td>CDS</td>
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<tr>
<td>Report from the LHC Fixed Target working group of the CERN Physics Beyond Colliders forum</td>
<td>Fixed Target Working Group</td>
<td>CDS</td>
</tr>
<tr>
<td>TECHNICAL PROPOSAL: FASER, THE FORWARD SEARCH EXPERIMENT AT THE LHC</td>
<td>FASER collaboration</td>
<td>CDS</td>
</tr>
<tr>
<td>The CERN Gamma Factory Initiative: An Ultra-High Intensity Gamma Source</td>
<td>Gamma Factory collaboration</td>
<td>IPAC (report in prep.)</td>
</tr>
<tr>
<td>Feasibility Study for a storage ring to search for an Electric Dipole Moment of charged particles</td>
<td>CPEDM</td>
<td>CDS (to be published)</td>
</tr>
<tr>
<td>nuSTORM at CERN: Feasibility Study</td>
<td>nuSTORM Working Group</td>
<td>CDS (to be published)</td>
</tr>
<tr>
<td>SPS Operation and Future Proton Sharing scenarios for the SHiP experiment at the BDF facility</td>
<td>Proton perf. post-LIU WG</td>
<td>CDS</td>
</tr>
</tbody>
</table>

see
http://pbc.web.cern.ch/
## Summary

- Class 4 for BDF, eSPS;
- Preliminary for nuSTORM
- Conventional beams – see PBC report
- Technology – all options – see PBC report

### Cost Scale

<table>
<thead>
<tr>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>&lt; few 100 kCHF</td>
</tr>
<tr>
<td>C2</td>
<td>From few 100 KCHF to 1-2 MCHF</td>
</tr>
<tr>
<td>C3</td>
<td>From 1-2 to 5-10 MCHF</td>
</tr>
<tr>
<td>C4</td>
<td>~10-50 MCHF</td>
</tr>
<tr>
<td>C5</td>
<td>&gt; 50 MCHF</td>
</tr>
<tr>
<td>C6</td>
<td>&gt; 150 MCHF</td>
</tr>
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</table>

### Table

<table>
<thead>
<tr>
<th>Project</th>
<th>Status</th>
<th>Deploy</th>
<th>Cost</th>
<th>Physics</th>
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<tbody>
<tr>
<td>BDF/SHIP, tauFV</td>
<td>CDS</td>
<td>LS3+</td>
<td>C6</td>
<td>Hidden Sector</td>
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<tr>
<td>eSPS/LDMX</td>
<td>Eol</td>
<td>&lt;LS3</td>
<td>C5</td>
<td>DM</td>
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<td>nuSTORM</td>
<td>CDS</td>
<td>LS3++</td>
<td>C6</td>
<td>Neutrinos</td>
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<td>CB/KLEVER</td>
<td>Eol</td>
<td>LS3+</td>
<td>C3</td>
<td>Precision</td>
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<td>CB/COMPASS-RFSB</td>
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<td>LS3+</td>
<td>C4</td>
<td>QCD</td>
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<td>NA62++</td>
<td>studies</td>
<td>Run 3</td>
<td>C1</td>
<td>Hidden Sector</td>
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<tr>
<td>NA64++</td>
<td>OP</td>
<td>Run 3</td>
<td>C1</td>
<td>DM</td>
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<tr>
<td>MUnE</td>
<td>proposal</td>
<td>Run3</td>
<td>C2</td>
<td>muon anomaly</td>
</tr>
</tbody>
</table>

### Other Projects

- **LHC**
  - LHC FT - gas: TP, Run 3, C1, PDF, DY, spin
  - LHC FT - crystal: proto, Run 3, C2, MDM/EDM

- **FASER**
  - TP/approval, Run 3, C2, LLP

- **MATHUSLA**
  - LOI, LS3, C5, LLP

- **CODEX-b**
  - LOI, LS3, C3, LLP

- **milliQan**
  - demo, Run 3, C2, LLP

### NOVEL

- **Gamma Factory PoP**
  - Eol, Run 3, C2, PSI/Laser

- **pEDM prototype**
  - CDS, 2022, C4, EDM

- **AWAKE++**
  - exploratory, LS3+, C4, DM

### PS

- **REDTOP**
  - proposal, LS3+, C3, BSM+

### TECHNOLOGY

- **VMB**
  - LOI, Run 3, C2, VMB

- **BabyJURA, JURA1, JURA 2**
  - proposal, 2023, C2, C2, C4, ALPs

- **BabyIAXO/IAXO**
  - advanced, 2023, C3, C4, Axions
Approximate “ideal” timelines