European Strategy Update

Programs of Large European and National Labs

(The role of regional research infrastructures in the ESPP 2020)

P. Campana (LNF INFN) – Granada Symposium – 15.05.2019

Scope of the talk

To highlight the role and the opportunities offered by Large European and National Laboratories (LENL) through their infrastructures, as one of the key ingredients of the 2020 European Strategy for Particle Physics (ESPP 2020)

Inputs to the talk

The submitted material to the ESPP 2020, and discussions at meetings of the Laboratory Directors Group at CERN

Disclaimer

Given the breadth of the subject, it is impossible to report on all on-going programs at LENL. The few examples presented here are based on a personal choice, and I apologise for omissions, inaccuracies, …

Definition

LENL are European regional infrastructures of large-medium size, operated at national level, which are strongly collaborating either in large programs at CERN, or in activities of interest of ESPP 2020, performed locally or at other European/International facilities

Intentional omissions

1) *Not discussing* CERN based projects: presented elsewhere at the Meeting
2) *Not discussing* the "experiment-style collaborations" among LENL for building and operating HEP experiments at CERN and elsewhere. This is a very well established network, whose contribution to ESPP 2020 is clear and identified through "solid channels". Also support from LENL to HEP computing not presented
3) *Not discussing* large international projects, such as SuperKEKb, DUNE & Neutrino platform, ILC, EIC, etc … where European Labs already contribute. These programs are presented elsewhere at the Meeting

The aim of the talk is to identify a "*fil rouge*" through the (nationally based) activities of LENL, to show their key role in contributing successfully to large research endeavours at CERN and elsewhere, in the framework of ESPP 2020

The role of LENL in ESPP 2013
(highlighted, although distributed under several headings)

d) … CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.

h) Experiments studying quark flavour physics, investigating dipole moments, searching for charged-lepton flavour violation and performing other precision measurements at lower energies, such as those with neutrons, muons and antiprotons … can be based in national laboratories, with a moderate cost and smaller collaborations. Experiments in Europe with unique reach should be supported, as well as participation in experiments in other regions of the world.

i) … Detector R&D programmes should be supported strongly at CERN, national institutes, laboratories and universities.

p) … CERN, together with national funding agencies, institutes, laboratories and universities, should continue supporting and further develop, coordinated programmes for education and training.

The LENL contributions to ESPP 2020: 4 main pillars

1. Network of LENL & Institutes involved in supporting CERN programs (HL-LHC, FCC, CLIC, PBC, etc….) or other large projects located elsewhere [fostering strategic coordination]

2. LENL running local projects, R&D activities, and providing infrastructures not replicated at CERN [developing technological complementarity]

3. LENL with facilities available to host fundamental physics experiments (beams, technical services, etc…) [implementing cultural diversity]

4. Contribution of LENL (especially if grouped in networks) to general progress of "third mission" in Training & Education, in Outreach and Knowledge Transfer [enlarging societal impact]

Points 2 & 4 must be considered vital for National Labs sustainability, i.e. to get stable national funding and a better access to the EU opportunities

Common items among LENL

- Collaborations with CERN & international projects
- Developing national programs for new technologies in HEP
- Providing facilities for experiments and tests (beam lines et al.)
- Participating to European Networks (AMICI, ARIES, EUROCIRCOL, TIARA, ATTRACT, AIDA2020, COMPACT XLS, EuPRAXIA, ALEGRO, LEAPS, …) devoted to develop future accelerator and detector technologies, Technology Transfer to European industry, industrial access to Research Laboratories Facilities
- Providing hubs & infrastructures for other nearby fields, where accelerator technologies are critical: astro-particle physics (e.g. ET telescope) or space science
- Playing a "*catalytic role*" in other science fields (computing, bio-sciences, environment, etc …), making use of HEP well-known organizational capabilities, together with long-term based infrastructures
- Sustain effort for science and STEM promotion among general public

Fruitful synergies with other communities are going well beyond boundaries of Particle Physics (and of ESPP 2020)

- Strong links with the network of Light Source Synchrotrons and FELs (LEAPS*), focused on R&D for accelerator components [DESY, X-FEL, ESRF, Diamond, PSI, Max IV, Soleil, Alba, Elettra, etc…]

- Interplay of research activities with Nuclear Physics facilities, that provide infrastructures, beam facilities, technology [Julich/COSY, GSI/FAIR, Mainz/MAMI-MESA, Bonn/ELSA, PSI, etc…] (input to ESPP 2020)

- Opportunities at other facilities, like neutron sources (LENS**), where fundamental physics programs can be exploited (n-EDM, $n \Leftrightarrow n_{bar}$, τ_N …), and users beam lines and irradiation facilities are available (input to ESPP 2020)

*LEAPS = League of European Accelerator-based Photon Sources
**LENS = League of advanced European Neutron Sources

Relevant examples of distributed/complementary activities (incomplete list, taken from ESPP 2020 inputs and elsewhere)

- Efforts in superconductive high magnetic field technologies (SC & HTS)
- Axion and Dark Sector searches
- Fundamental physics at low energy facilities
- Science with intense muon beams
- Storage rings for charged particle EDM experiments
- RF-based compact accelerators
- Plasma acceleration with beam- or laser-wake fields
- Study of novel ideas on muon collider
- High intensity beams (Energy Recovery Linacs, p/ion drivers, CW beams, …)
- R&D for synchrotron light machines and FELs
- R&D on accelerators for medicine (CNAO, MedAustron, …)
- Beam test & irradiation facilities (sources of charged & neutral particles)
- Open infrastructures dedicated to accelerator industrial technologies
- Education & Training activities (Masterclasses, BL4S, Acc. & HEP Schools, etc…)
- Promoting infrastructures in developing countries (SESAME, …)

….

Fostering strategic coordination

Promoting collaborations of European Labs & Institutes to support strategic CERN large scale programs (HL-LHC, FCC, etc ...) or other international projects located elsewhere

Patio de Los Arrayanes – Pattern p3

Participation to large international projects: LHC, XFEL, ESS, ITER, FAIR, …

Recent years have seen an increasing role of LENL as strong partners of large European (and non-European) scientific endeavours

Making use of several different mechanisms (collaboration agreements, in kind contributions, partnerships, etc…), several success-stories have been built

LHC (HL-LHC) – LENL collaborated to several key elements of the machine
XFEL – The efforts of building and testing several components of the machine, shared among various LENL (cryo-modules, RF units, etc…)
ESS, ITER, FAIR, … same mechanism with construction responsibilities distributed at European level. An even major role in R&D played by LENL

A consolidated scheme with a very positive feed-back mechanism:
- LENL enhance/preserve their technological know-how
- Large projects acquire complementary competences and critical mass
- European industry return can be of high level
- Large infrastructures built on purpose can be useful for other projects

However, future machines projects set new challenges. One critical item …

Ultra-high magnetic fields for future machines

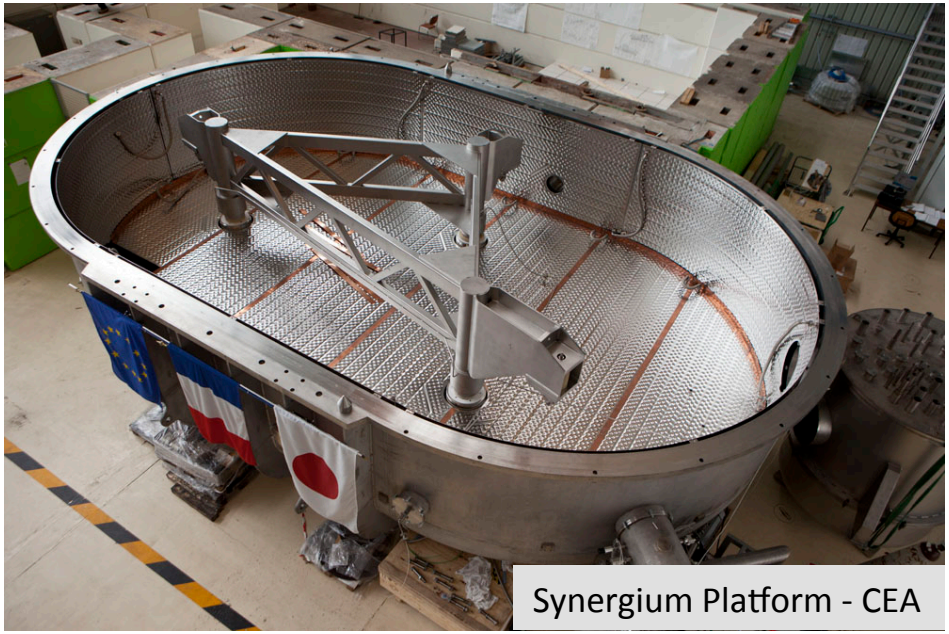
After the academic/industrial coordinated effort to build NbTi based SC LHC magnets, a new breakthrough is needed to satisfy the requests for future O(100 TeV) hadron colliders (FCC & SPPC)

Research focus concentrated on Nb_3Sn and HTS conductors. Nb_3Sn wire already needed for ITER and HL-LHC (modest quantities)
Large coordinated efforts at CERN and elsewhere (Europe, US, J, Kr, Ru), while industrial involvement is mandatory

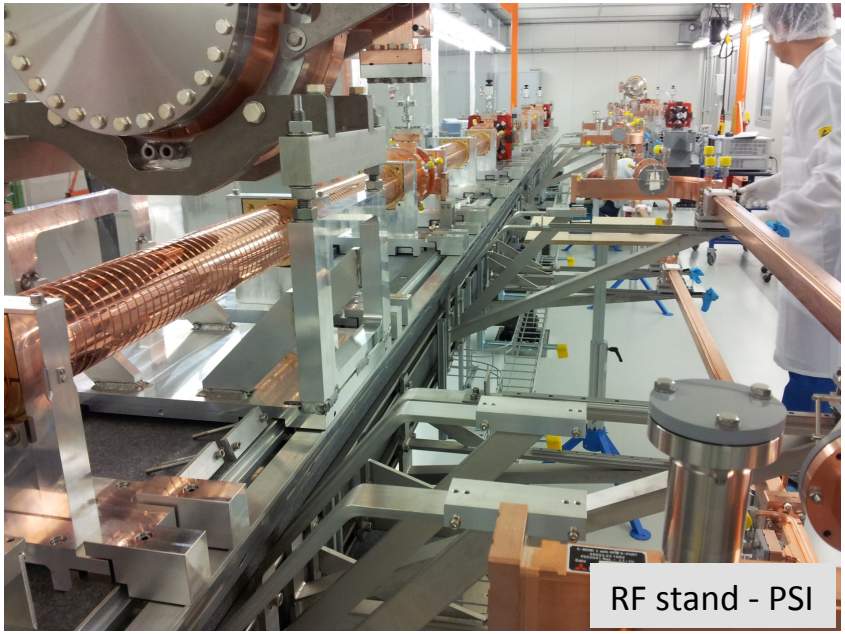
Collaboration based on H2020 EuroCirCol design study and on agreements:
- WP5 on-going R&D at CERN, TUT, CEA, INFN, UT, CIEMAT, KEK, UNIGE
- specific programs in place with CEA, CIEMAT (Prismac), CH (Chart), INFN, and more to come

An Open Lab for the development of superconductors has been proposed as a specific ESPP 2020 input (to be located somewhere in Europe)

The same collaboration with LENL holds for a large series of common activities on FCC (integration, vacuum, cryogenics, diagnostics, cavities, …)

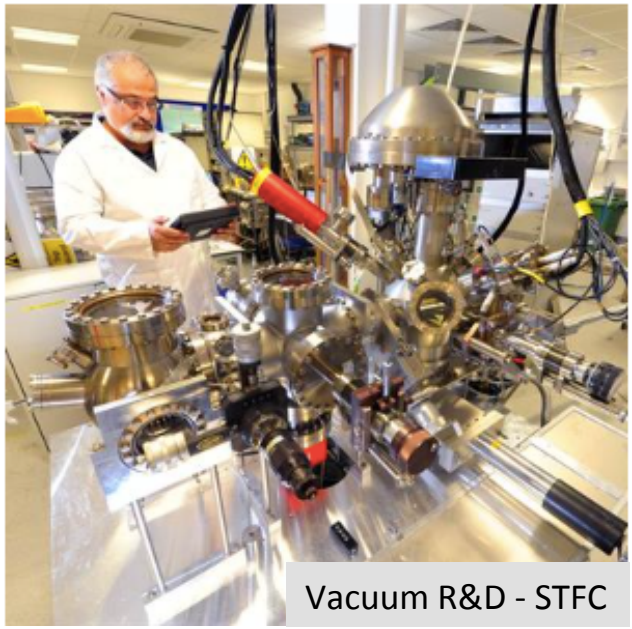


Synergium Platform - CEA



RF stand - PSI

Coupler stand- LAL

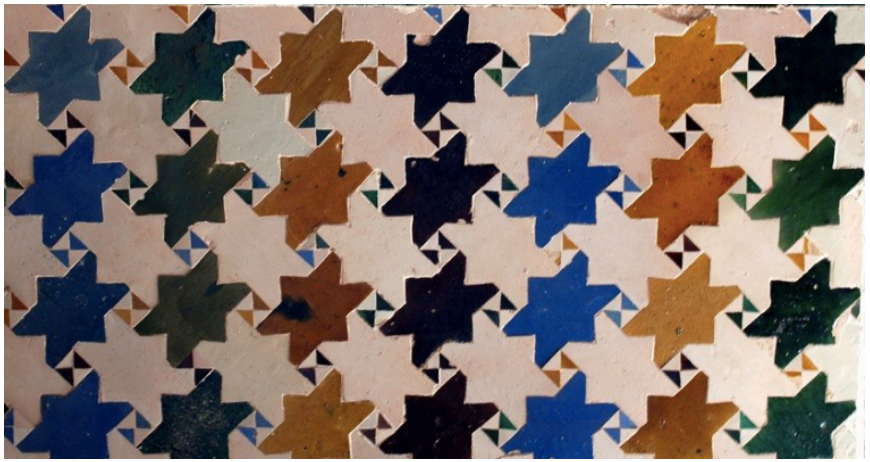


Vacuum R&D - STFC

Developing technological complementarity

LENL international and/or national programs, complementary to CERN activities, contribute to technological developments in fields related to ESPP 2020 and transfer innovative technologies towards European industry

Mexuar – Pattern p4g



High and Ultra High gradients/high power beams for future machines

Technological challenge to overcome current limitations in accelerating capabilities of present Linacs. Two main R&D lines:

- higher RF gradients (100-200 MV/m), CLIC-based studies on X-band
- plasma wake fields (1-10 GV/m), generated by laser or charged beams (e, p)

Several facilities operating in US (Facet, Bella), CERN (Awake) and elsewhere

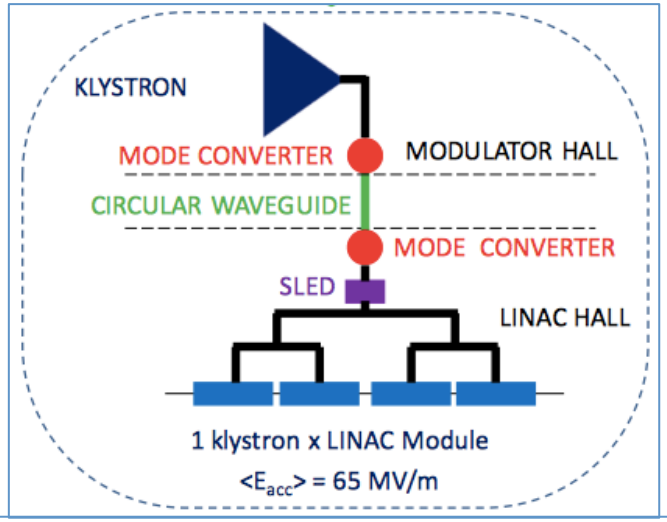
LENL (and CERN) are fully involved in H2020 design studies:

- Compact XLS, to design a e^- Linac facility based on X-band technology
- EuPRAXIA, to design a FEL operated by a plasma accelerating cell

and in ALEGRO, a study group towards Advanced HEP Linear Colliders

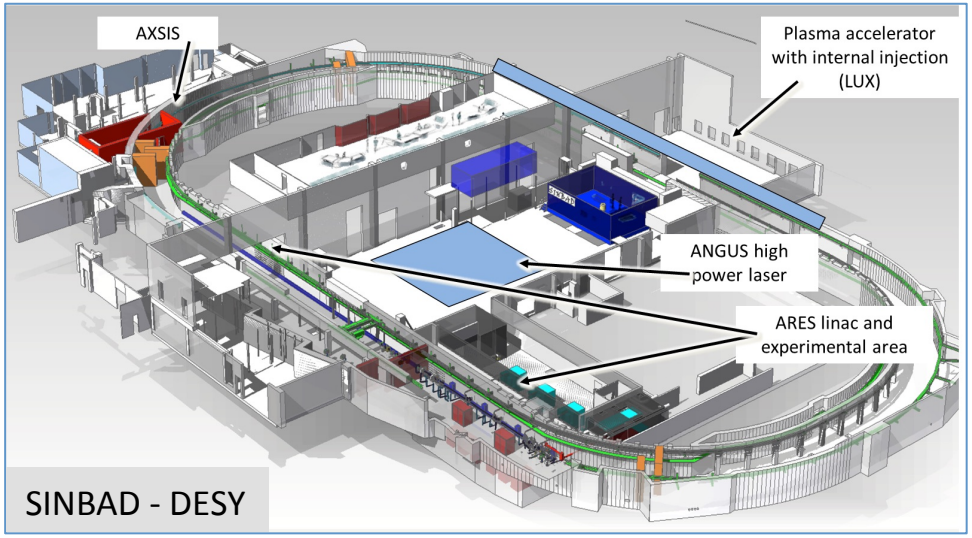
LENL and other Labs participate in this sector with existing facilities (including large laser infrastructures), or with planned future investments:
DESY (Sinbad, FlashFF) & the Helmholtz-ATHENA network, LNF (Sparc_Lab), STFC (VELA/CLARA, Central Laser Facility), CEA/CNRS (CILEX), SOLEIL, ELETTRA, PSI, ALBA, KARA, and a long list of collaborating Universities

A coordinated and large international effort in getting CW SCRF beams (e.g. at DESY-CMTB cryo-test stand), increasing Q factors & gradients.
Relevant to developments for LHeC and FCC-ee

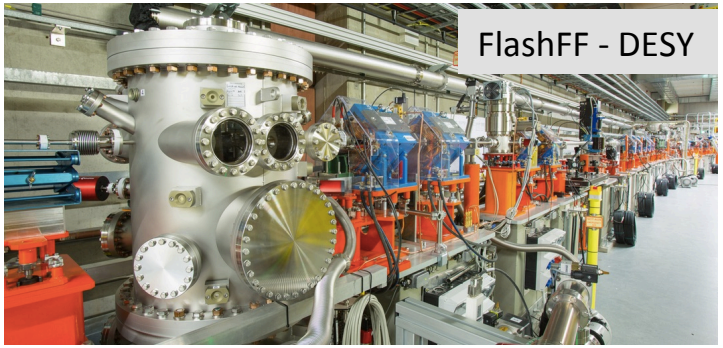


An unified X-band Linac sub-unit layout :

- for the CERN-eSPS Linac
- for the Compact XLS design study
- for the EuPRAXIA@SPARC_LAB Linac

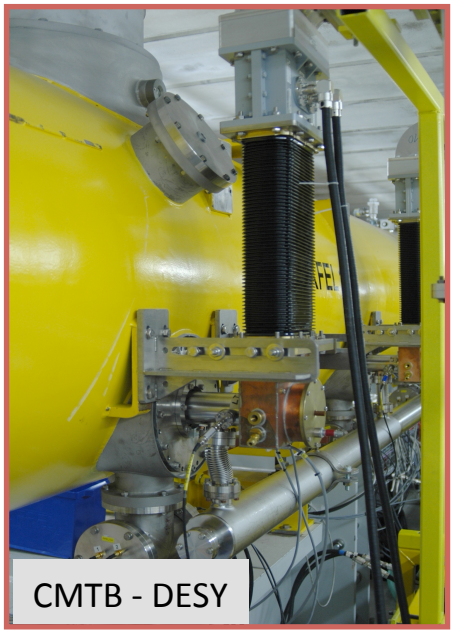


SINBAD - DESY

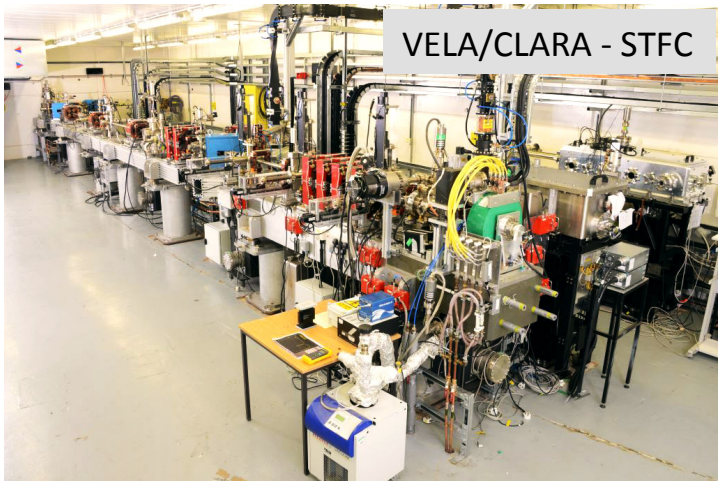


FlashFF - DESY

CILEX - Apollon



CMTB - DESY



VELA/CLARA - STFC

EuPRAXIA@SPARC_LAB - LNF

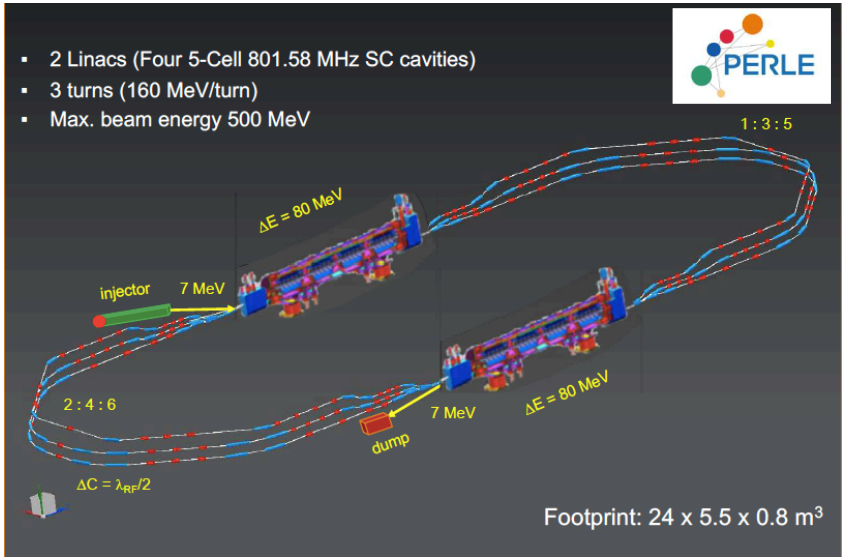
Infrastructures for innovation in accelerator technologies

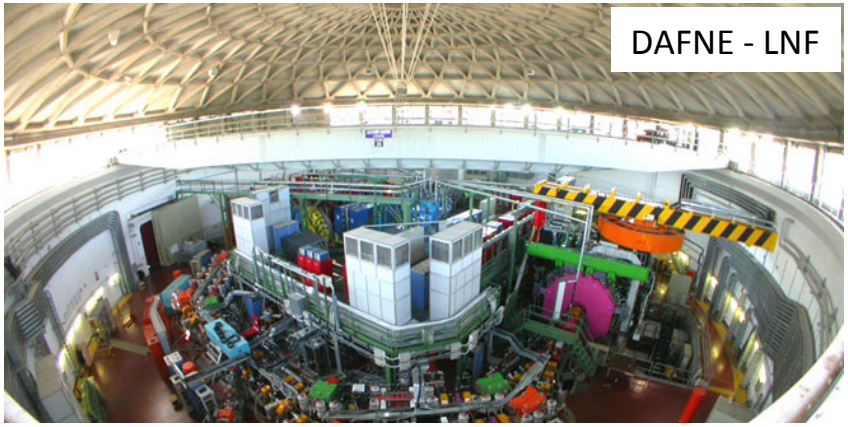
PERLE (LAL) is designed as a new generation facility reaching for the first time the 10MW power regime of e^- beam current and energy (ERL).
A "green" generation of high energy, high current e^- beams. A CEA, CNRS, STFC, BINP, JLAB, CERN and Darmstadt collaboration. Operational 2023-25.

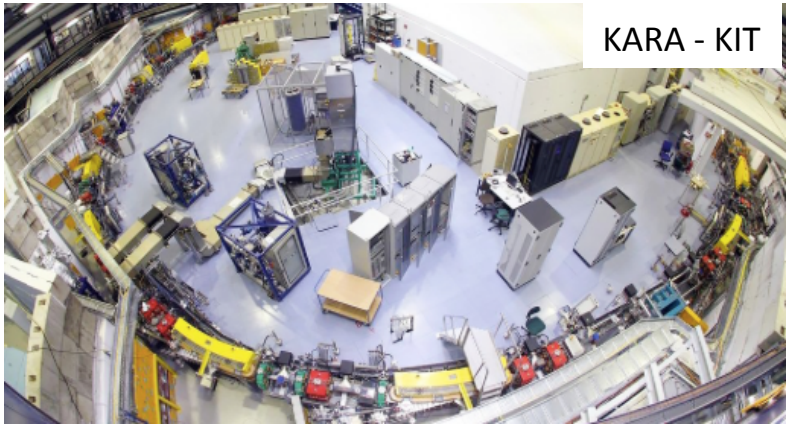
3 turns race track, 802 MHz SC cavities, 20 mA currents, E=500 MeV.
Test bed for future LHeC components and a potential host of high intensity e^- beam-based experiments (dark photons, e.w.k. physics, etc…)

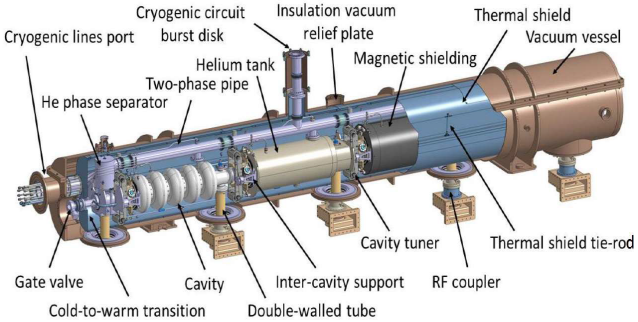
DAFNE (LNF) will terminate its collider mode operation in 2020. Proposal to transform it in a test facility for accelerator technologies in high e^- /e^+ currents, study of beam dynamics, source of extracted beams for dark photon searches, high flux Compton source, etc …

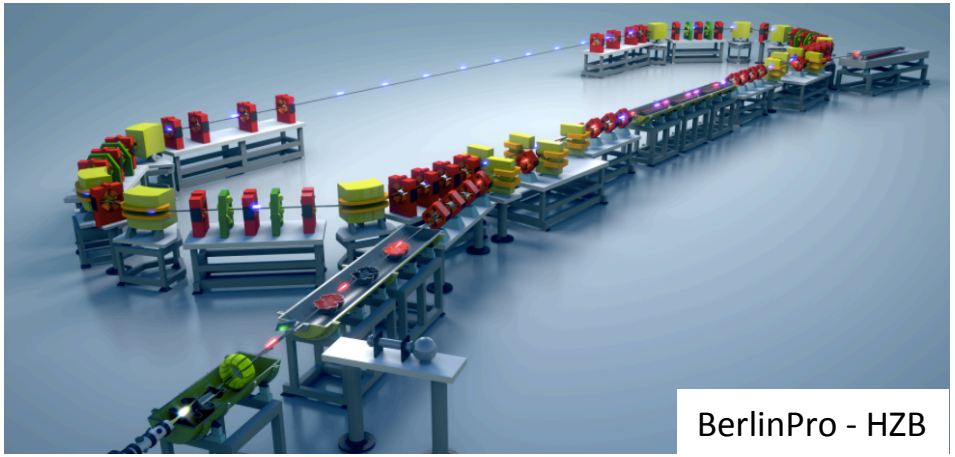
Several other European machines available/planned for R&D on accelerators: LAL/ThomX, high flux Compton source – HZDR/ELBE, high power rad. sources – HZB/BerlinPro, ERL & high brightness beams – Bonn/ELSA, polarized beams, beam dynamics – KIT/KARA, test with SC insertions, vacuum (FCC), etc …

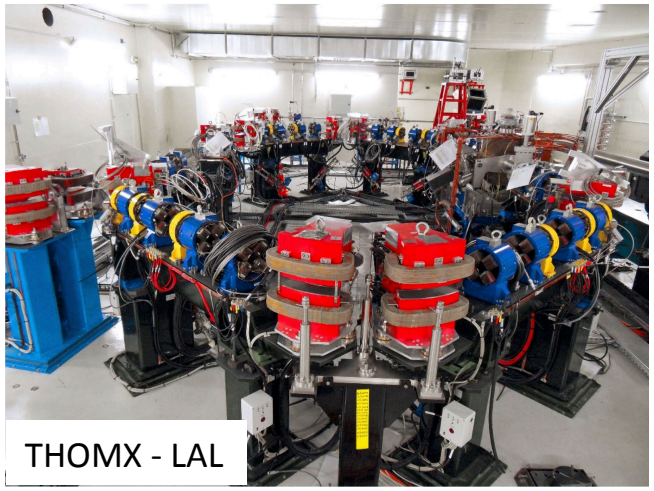

PERLE
2 Linacs (Four 5-Cell 801.58 MHz SC cavities)
3 turns (160 MeV/turn)
Max. beam energy 500 MeV
1 : 3 : 5
ΔE = 80 MeV
injector
7 MeV
2 : 4 : 6
7 MeV
ΔE = 80 MeV
dump
ΔC = λRF/2
Footprint: 24 x 5.5 x 0.8 m³


DAFNE - LNF


KARA - KIT


Cryogenic lines port
Cryogenic circuit burst disk
Insulation vacuum relief plate
Thermal shield
Vacuum vessel
Helium tank
Magnetic shielding
Two-phase pipe
He phase separator
Cavity tuner
Thermal shield tie-rod
Gate valve
Cavity
Inter-cavity support
RF coupler
Cold-to-warm transition
Double-walled tube


BerlinPro - HZB


THOMX - LAL

LENL facilities for beam testing and for irradiation studies

LENL provide test beam lines based on competitive selection/open access, together with a "best effort" technical support for users (thanks !)

Test beams*, status May 2019			
Laboratory	**No. of lines**	**Particles**	**Energy range**
DAFNE BTF Frascati (IT)	2	e+/e- both primaries and secondaries	25-750 MeV/c Rep Rate 50Hz - 1/40 ns 1 to 10^{10}p/pulse
DESY (D)	3	e+, e- (sec.) e- (prim., planned for 202X)	1 - 6 GeV/c 6.3 GeV/c
PSI (CH) piE1, piM1, etc.	2-4	π+-, μ+-, e+-, p	50-450 MeV/c, rate <10^9 sec^{-1} 20 ns structure cw at very high rate
PSI / PIF (CH)	1	p	5 - 230 MeV/c max. current 2 - 5 nA, rate <10^9 sec^{-1}, typ. flux 10^8 cm^{-2} $sec^{-1}$for wide beam,
University of Bonn ELSA (D)	1	e-	Energy range: 1.2 - 3.2 GeV/c rate: ~500Hz - 1 GHz
University of Mainz MAMI (D)	3	e- gamma	Energy range for e- and gamma beam: < 1.6 GeV/c e- intensity < 0.1 mA

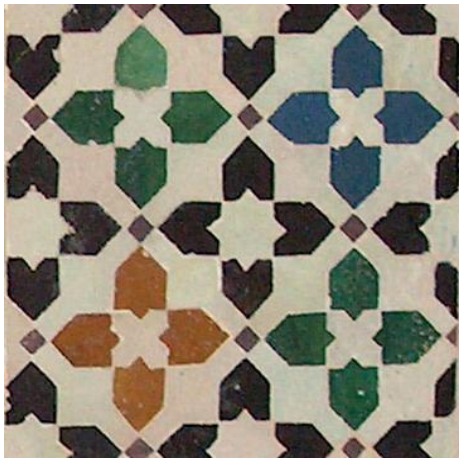
***Beam lines with beams p> 100 MeV/c. Compilation by H. Wilkens (CERN)**

A long list of irradiation facilities also available (http://irradiation-facilities.web.cern.ch/)

Implementing cultural diversity

LENL provide infrastructures or accelerators able to host high impact fundamental physics experimental programs. These activities enhance cultural spectrum and complementarity in our field, providing resources and opportunities to new, emerging communities

Mirador de Linderaja – Pattern p4m



Sala de los Reyes – Pattern p6m

Axions and Dark Sector searches

A vivid, growing community, several techniques. Several inputs to ESPP 2020. Active and organized throughout Europe, America, Asia

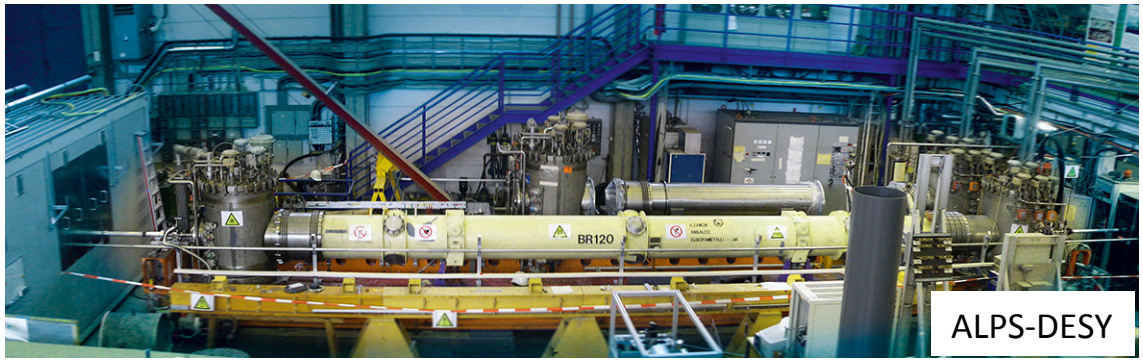
Axions (ALPS) searches, are now challenging experiments requiring large technical resources (halls, cryogenics, mechanics, vacuum, RF, detectors, DAQ):

- "light shine through the wall" , long strings of high field SC HERA magnets (DESY – ALPSII), STAX
- Helioscopes (DESY – babyIAXO), IAXO
- Haloscopes (LNF – KLASH, DESY – MADMAX)

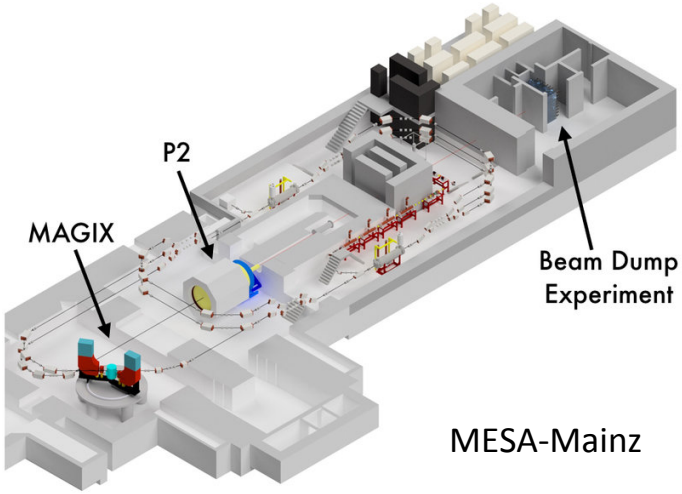
(+ activities at CERN - JURA et al., and elsewhere)

Search for Dark Sector asks for high current $e^{\pm}$ beam dump experiments. Experiments on-going/planned at existing and future facilities throughout the world: CERN (NA64, LDMX), Mainz (BDX, MAGIX), LNF (Padme) + US, J, Ru

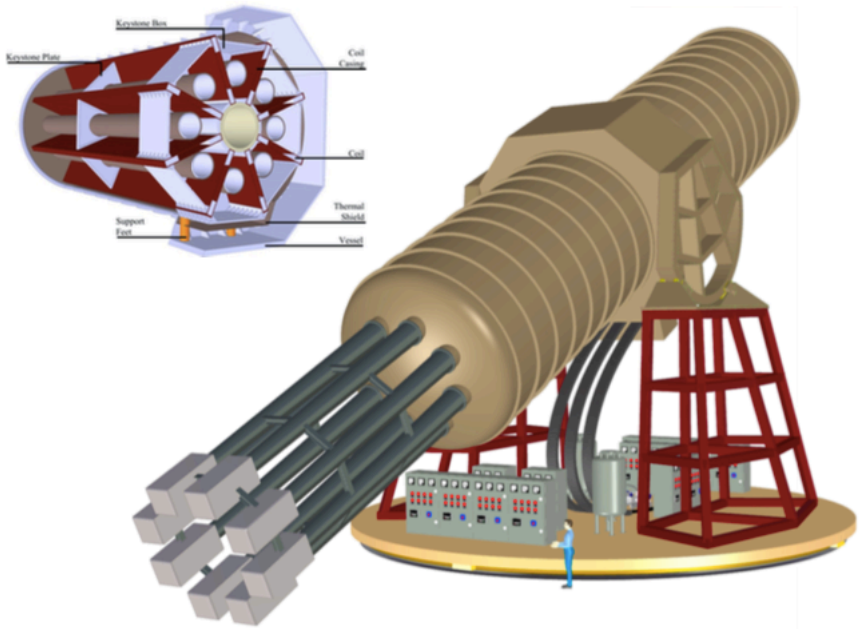
Two well-motivated communities, supported by solid theory *fan-groups*, which will ask in the coming years for technical and manpower resources at LENL, as experiments are no longer table-top ones



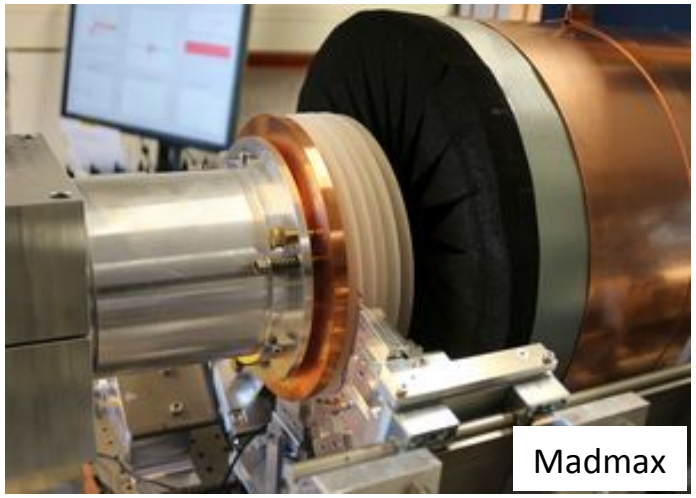
ALPS-DESY



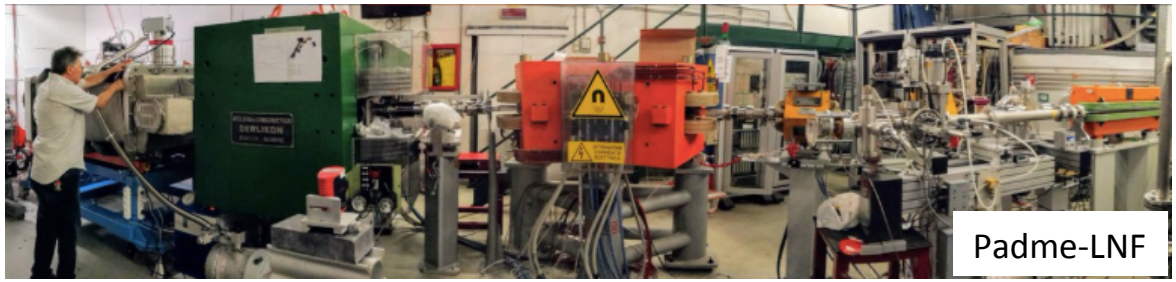
MESA-Mainz



IAXO



Madmax



Padme-LNF

Charged Particle Electric Dipole Moment Searches

Highly complex technology with non-standard accelerator techniques (ultra-high precision electrostatic bending). CPEDM Collaboration preparing a roadmap for future experiments: specific input at ESPP 2020

1 Precursor Experiment	→	2 Prototype Ring	→	3 All-electric Ring
dEDM proof-of-capability (orbit and polarization control; first dEDM measurement)		**pEDM proof-of-principle** (key technologies, first direct pEDM measurement)		**pEDM precision experiment** (sensitivity goal: 10^{-29} e cm)
- Magnetic storage ring - Polarized deuterons - d-Carbon polarimetry - Additional E-field by RF Wien-filter		- High-current all-electric ring - Simultaneous CW/CCW op. - Frozen spin control (with combined E/B-field ring) - Phase-space beam cooling		- Frozen spin all-electric (at p = 0.7 GeV/c) - Simultaneous CW/CCW op. - B-shielding, high E-fields - Design: cryogenic, hybrid,…
Ongoing at COSY (Jülich) 2014 → 2021		Ongoing within CPEDM 2017 → 2020 (CDR) → 2022 (TDR) Start construction > 2022		After construction and operation of prototype > 2027

Julich (COSY) is a possible Lab where to build the proof-of-concept and the final storage ring to measure p-EDM at unprecedented level.
Another nice example of collaboration among several LENL & CERN

cLFV with high intensity muon beams

Charged-lepton flavour-violating (cLFV) processes are deep probes for new physics with discovery sensitivity to a broad array of new physics models at high scale mass values. The most sensitive probes of cLFV utilize high-intensity, low-momentum muon beams to search for $\mu \rightarrow e$ transitions.
An intense experimental program at PSI, FNAL, JPARC

The HIPA infrastructure at PSI, with a 1.4 MW proton facility, offers the highest intensity of μ (and π) low momentum beams (p_μ=28 MeV/c, 10^8 μ^+_{STOP} /s).
MEG (running) and Mu3e (in preparation) experiments

Upgrade program for beam line (HiMB), aiming to x100 intensity is planned, to feed MEG and Mu3e Phase2 experiments (> 2024)

Other interesting opportunities at PSI muon beam lines:

- mu-Cool, muon cooling to reduce beam phase space by 10^{-10} with $\varepsilon=10^{-3}$
- other fundamental physics experiments with low momentum muons: μ-EDM and studies on muonium (determination of μ mass: impact on g-2)

Other fundamental science opportunities at European facilities

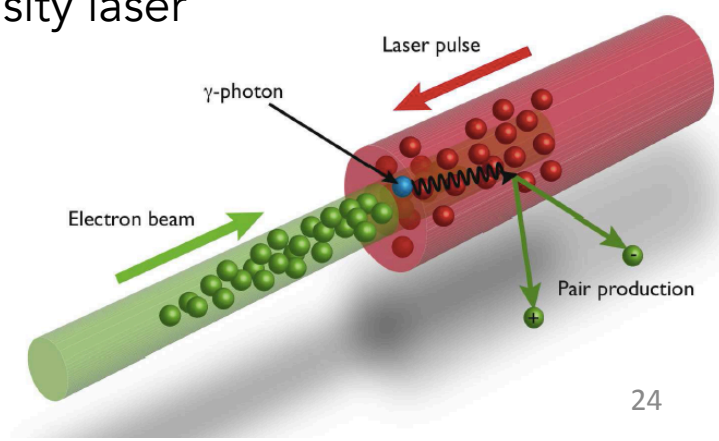
Availability on n sources throughout Europe stimulated other programs:

- HIBEAM/NNBAR program at ESS, to measure Δ=1,2 baryonic number transitions with n sterile production and n $\Leftrightarrow$ n_{BAR} oscillations. Fundamental Physics Beamline (HIBEAM, >2024) and Large Beam Port (NNBAR, >2030) to be made available by ESS
- n-EDM research programs at ILL, Munich FR2, PNPI and PSI UCN
- n-lifetime measurement in experiments with beam- or storage-based techniques at (mainly) ILL

Interesting initiative at XFEL with the 17 GeV e^- beam line:

- LUXE, a test of QED in extreme conditions, beyond the Schwinger limit of 10^{16} V/cm: high energy e^- against high intensity laser

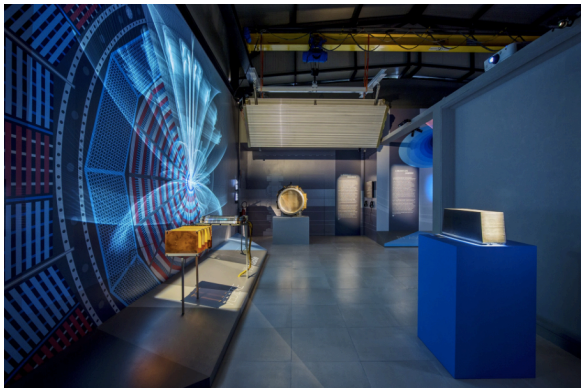
Similar Astra-Gemini experiment at STFC laser facility with laser driven e^- beam



Enlarging societal impact

LENL infrastructures provide added value to already large Outreach & Education activities performed by Academic Institutions, considering:

- On site and hand-on training opportunities for scientists and technicians
- A unique class of instruments available (operating accelerators is a typical example), including for outreach use (e.g. the BL4S program)
- Running Open Days/Visits where a large amount of public is confronted with science and scientists, and it is impressed by hardware
- Possibilities of hosting Visitor Centres and sharing material/exhibitions among LENL (in collaboration with the new Science Gateway at CERN)
- Promoting and easing mobility among researchers, of extreme and durable value as witness of world-wide impact of Science



Same considerations hold for KT and for the impact on economy and on societal wellness. LENL can play the role of Open Infrastructures for KT, especially to SMI, who do not have resources to build costly apparatus but need an access to them to test or implement advanced products

As an example, the AMICI H2020 project addresses the task to strengthen the capabilities of European firms in the innovative markets making use of accelerator technologies. All major LENL are involved

Critical mass and organizational resources allow LENL to host incubator initiatives to promote research spin-offs and start-up companies

An added value is represented by the "CERN style" way of managing large, heterogeneous collaborations in a unique way

These assets are more and more key ingredients of sustainability of LENL

Conclusion

LENL contributions provide a benchmark in Collaborative Science models

They can play relevant roles not only in the progress of the projects and activities that will be part of ESPP 2020, but, at large, on collateral fields

Highlighting this message in the Strategy will generate a positive interference for the challenging future endeavors, and send a significant message to National Funding Agencies (and to European Commission), to provide to them an adequate support

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