# Roadmap for ARIES APEC

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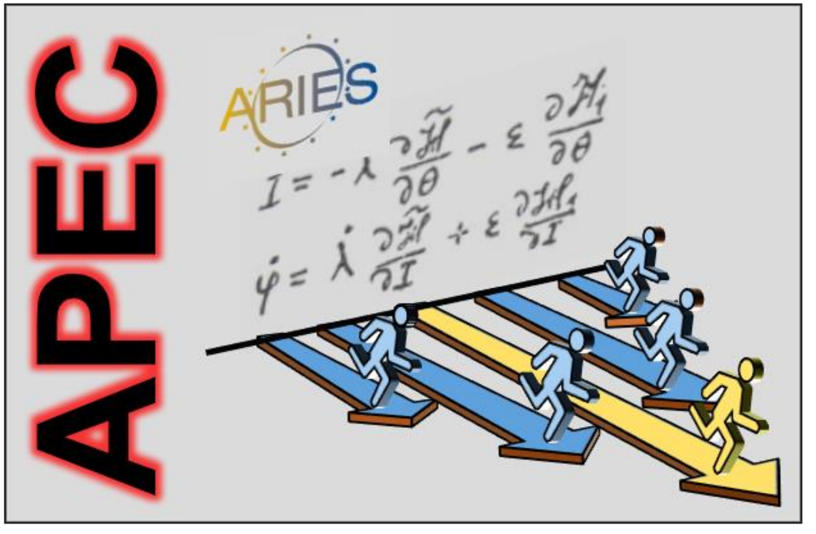
# **A**ccelerator **Pe**rformance and **C**oncepts
# **APEC**

## WP 6




Network-Activity

# Description

*The APEC network comprises 5 scientific tasks, addressing both presently important as well as far-future topics, with an emphasis on beam quality and performance control.. The tasks relate to*

*A. Beam Quality in Hadron Storage Rings and Synchrotrons, with particular importance for FAIR, the HL-LHC upgrade, and FCC-hh;*

*B. Reliability and Availability of Particle Accelerators, in numerous fields of application;*

*C. Improved beam stabilization, covering impedance models, impedance reduction, electron-cloud mitigation, and feedback systems;*

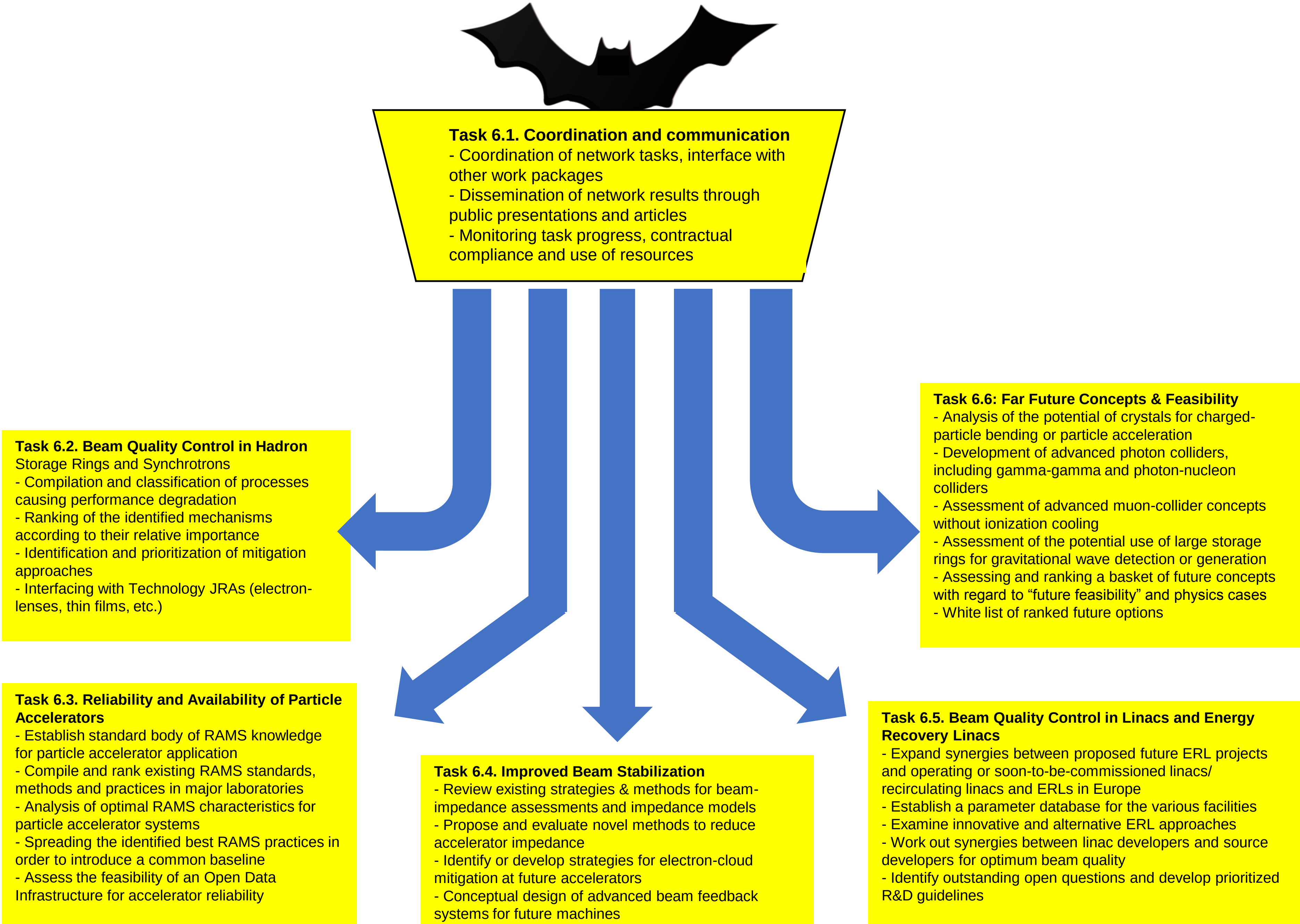
*D. Beam Quality Control in Linacs and Energy-Recovery Linacs, addressing novel aspects of multi-turn systems in view of MESA, LHeC and FCC;*

*E. Far-future concepts and their “feasibility”, including crystal applications, photon colliders, and gravitational waves in accelerators, and the delivery of a final white list of ranked options.*

*APEC is the successor of the earlier networking activities EuCARD-2 XBEAM, EuCARD-AccNet, and CARE-HHH. It is building on the foundations laid in the past with a reoriented and forward looking scope.*

# Impact

*APEC will connect separate communities and projects confronting similar challenges (for example, FAIR and the LHC in task 2; ESS, LHC, light sources and medical accelerators in task 3; MESA, LHeC, ALICE, TU Darmstadt, and Berlin PRO in task 5) so as to foster the exchange of ideas, joint progress and the development of synergies. APEC aims at improving the performance of the next generation of accelerators and colliders, at advancing the design of the "next next" generation of accelerators, and at investigating and ranking options for the long-term future. APEC will provide important input to the next update of the European Strategy for Particle Physics expected in 2019.*

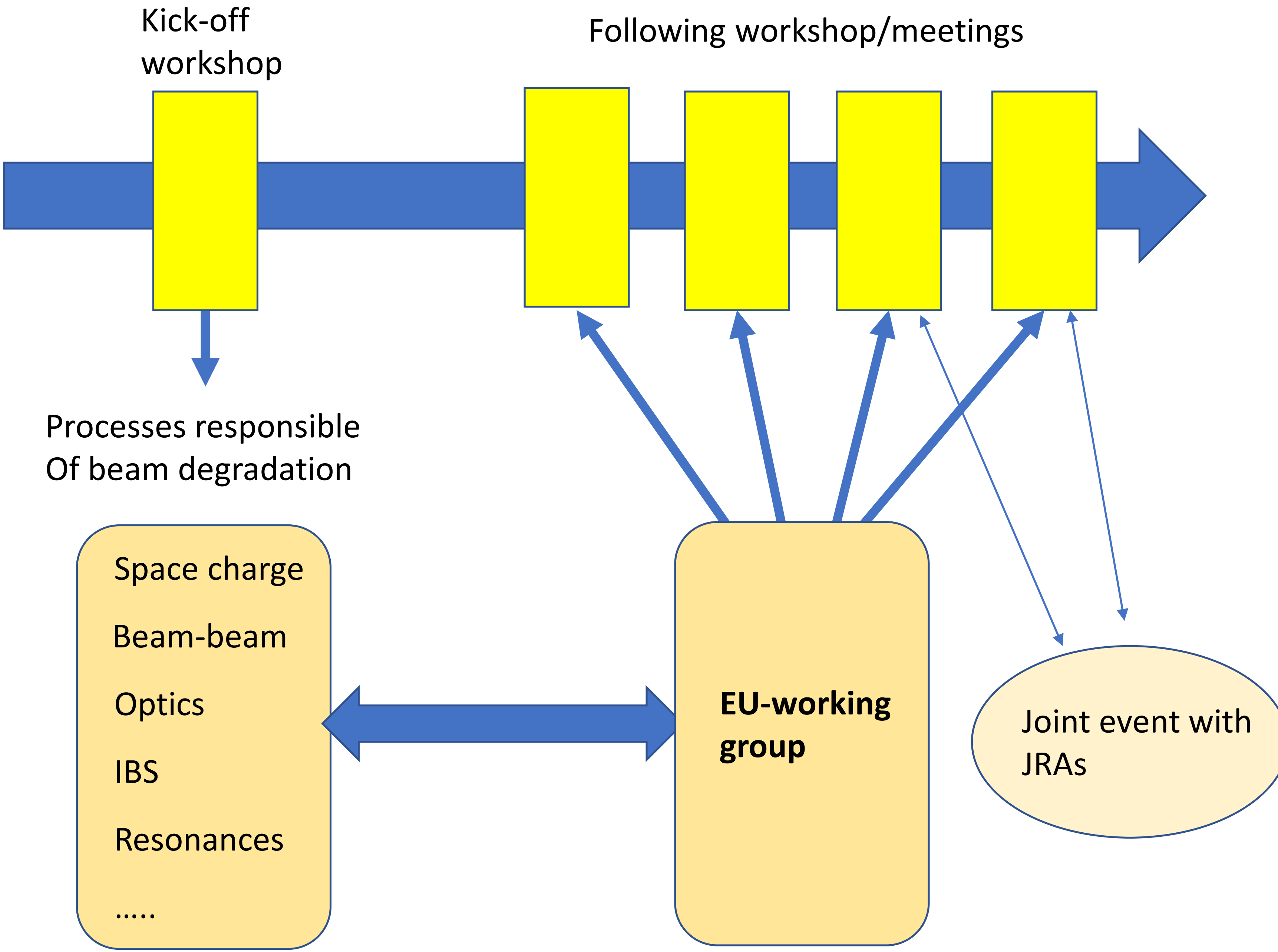


Task 6.1. Coordination and communication
- Coordination of network tasks, interface with other work packages
- Dissemination of network results through public presentations and articles
- Monitoring task progress, contractual compliance and use of resources
Task 6.2. Beam Quality Control in Hadron Storage Rings and Synchrotrons
- Compilation and classification of processes causing performance degradation
- Ranking of the identified mechanisms according to their relative importance
- Identification and prioritization of mitigation approaches
- Interfacing with Technology JRAs (electron-lenses, thin films, etc.)
Task 6.6: Far Future Concepts & Feasibility
- Analysis of the potential of crystals for charged-particle bending or particle acceleration
- Development of advanced photon colliders, including gamma-gamma and photon-nucleon colliders
- Assessment of advanced muon-collider concepts without ionization cooling
- Assessment of the potential use of large storage rings for gravitational wave detection or generation
- Assessing and ranking a basket of future concepts with regard to “future feasibility” and physics cases
- White list of ranked future options
Task 6.3. Reliability and Availability of Particle Accelerators
- Establish standard body of RAMS knowledge for particle accelerator application
- Compile and rank existing RAMS standards, methods and practices in major laboratories
- Analysis of optimal RAMS characteristics for particle accelerator systems
- Spreading the identified best RAMS practices in order to introduce a common baseline
- Assess the feasibility of an Open Data Infrastructure for accelerator reliability
Task 6.4. Improved Beam Stabilization
- Review existing strategies & methods for beam-impedance assessments and impedance models
- Propose and evaluate novel methods to reduce accelerator impedance
- Identify or develop strategies for electron-cloud mitigation at future accelerators
- Conceptual design of advanced beam feedback systems for future machines
Task 6.5. Beam Quality Control in Linacs and Energy Recovery Linacs
- Expand synergies between proposed future ERL projects and operating or soon-to-be-commissioned linacs/ recirculating linacs and ERLs in Europe
- Establish a parameter database for the various facilities
- Examine innovative and alternative ERL approaches
- Work out synergies between linac developers and source developers for optimum beam quality
- Identify outstanding open questions and develop prioritized R&D guidelines

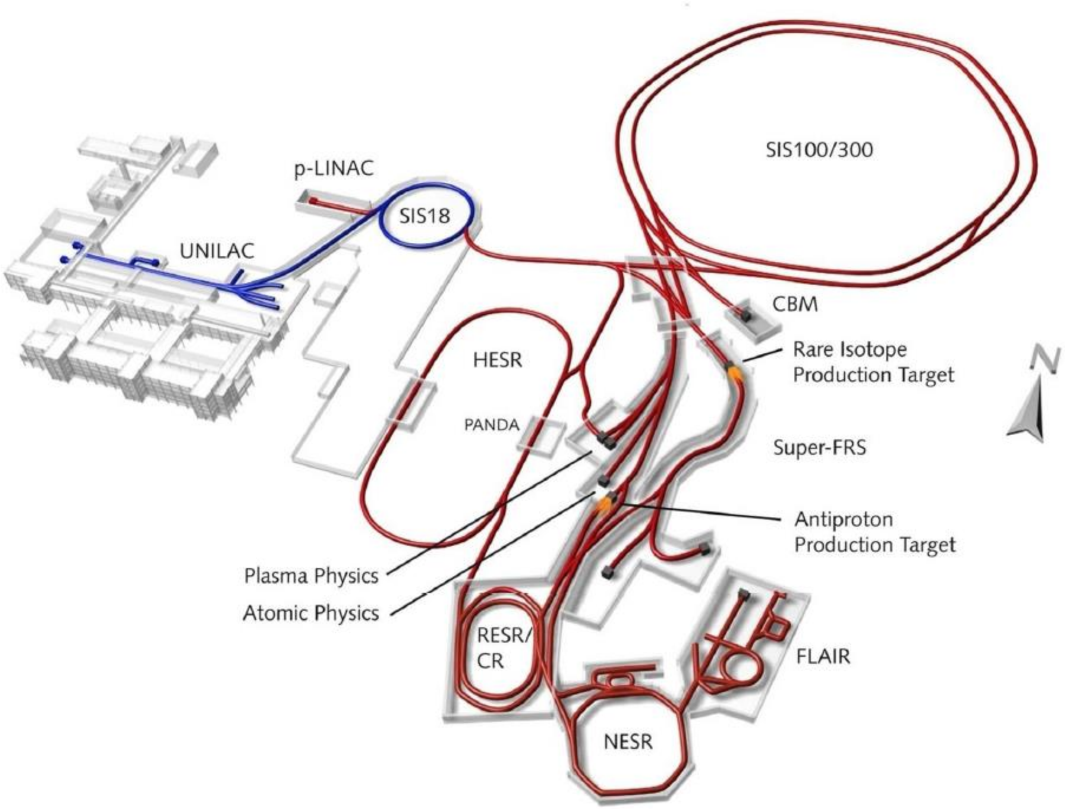
**Task 6.2. Beam Quality Control in Hadron Storage Rings and Synchrotrons (CERN, GSI)**

Within the framework of an initial workshop, the task will compile and classify the processes causing performance degradation in past, existing and planned facilities (LHC, SPS, SIS18, SIS100, RHIC, Tevatron). The identified mechanisms will be ranked according to their relative importance for future machines (HL-LHC, FAIR, FCC-hh). At the first workshop also a European working group with representatives from several institutions will be formed to steer the activities. In later workshops this working group will identify and prioritize the mitigation approaches. Some of these events will be jointly organized with some of the technology JRAs, e.g. to assess measures like electron-lenses, thin-film coatings, etc.

- Compilation and classification of processes causing performance degradation
- Ranking of the identified mechanisms according to their relative importance
- Identification and prioritization of mitigation approaches
- Interfacing with Technology JRAs (electron-lenses, thin films, etc.)


Kick-off
workshop
Following workshop/meetings
Processes responsible
Of beam degradation
Space charge
Beam-beam
Optics
IBS
Resonances
.....
EU-working
group
Joint event with
JRAs

# FAIR




## Primary Beams

- $5x10^{11}$/s; 1.5-2 GeV/u; $^{238}U^{28+}$
- Factor 100-1000 over present in intensity
- $2x10^{13}$/s 30 GeV protons
- $10^{10}$/s $^{238}U^{73+}$ up to 35 GeV/u
  (up to 90 GeV protons)

## Secondary Beams

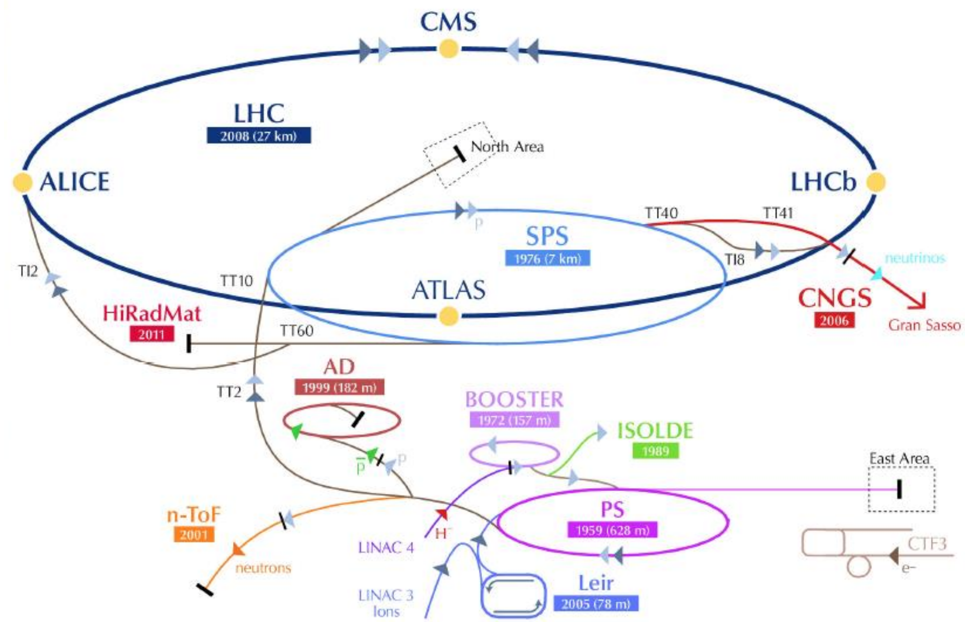
•Broad range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 in intensity over present
•Antiprotons 3 - 30 GeV

## Storage and Cooler Rings

•Radioactive beams
•e – A collider
•$10^{11}$ stored and cooled 0.8 - 14.5 GeV antiprotons

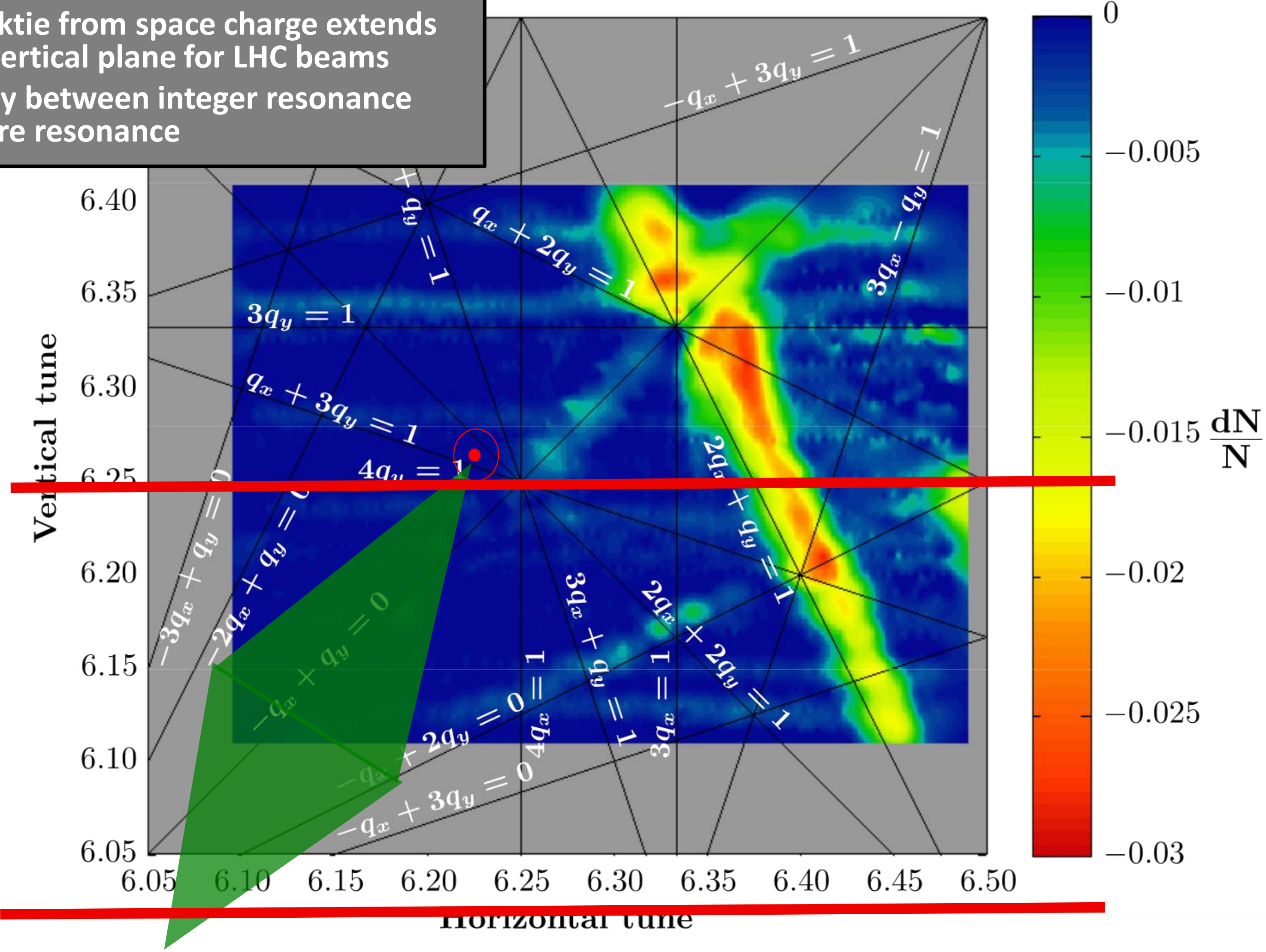
## Key Technical Features

•Cooled beams
•Rapidly cycling superconducting magnets

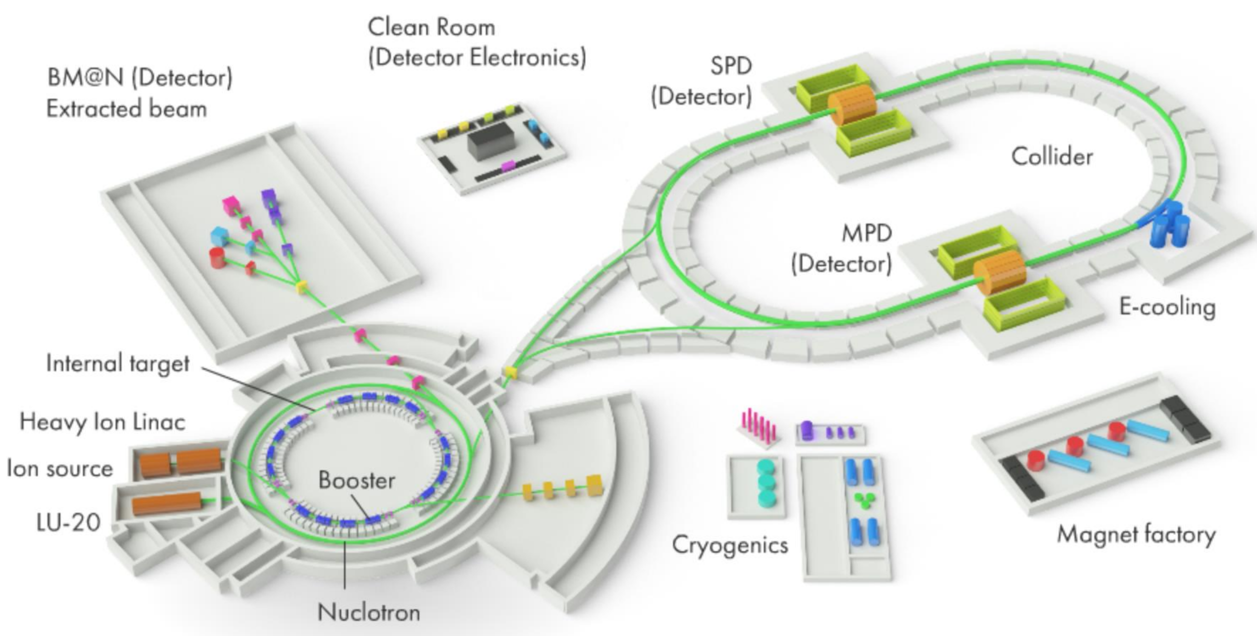


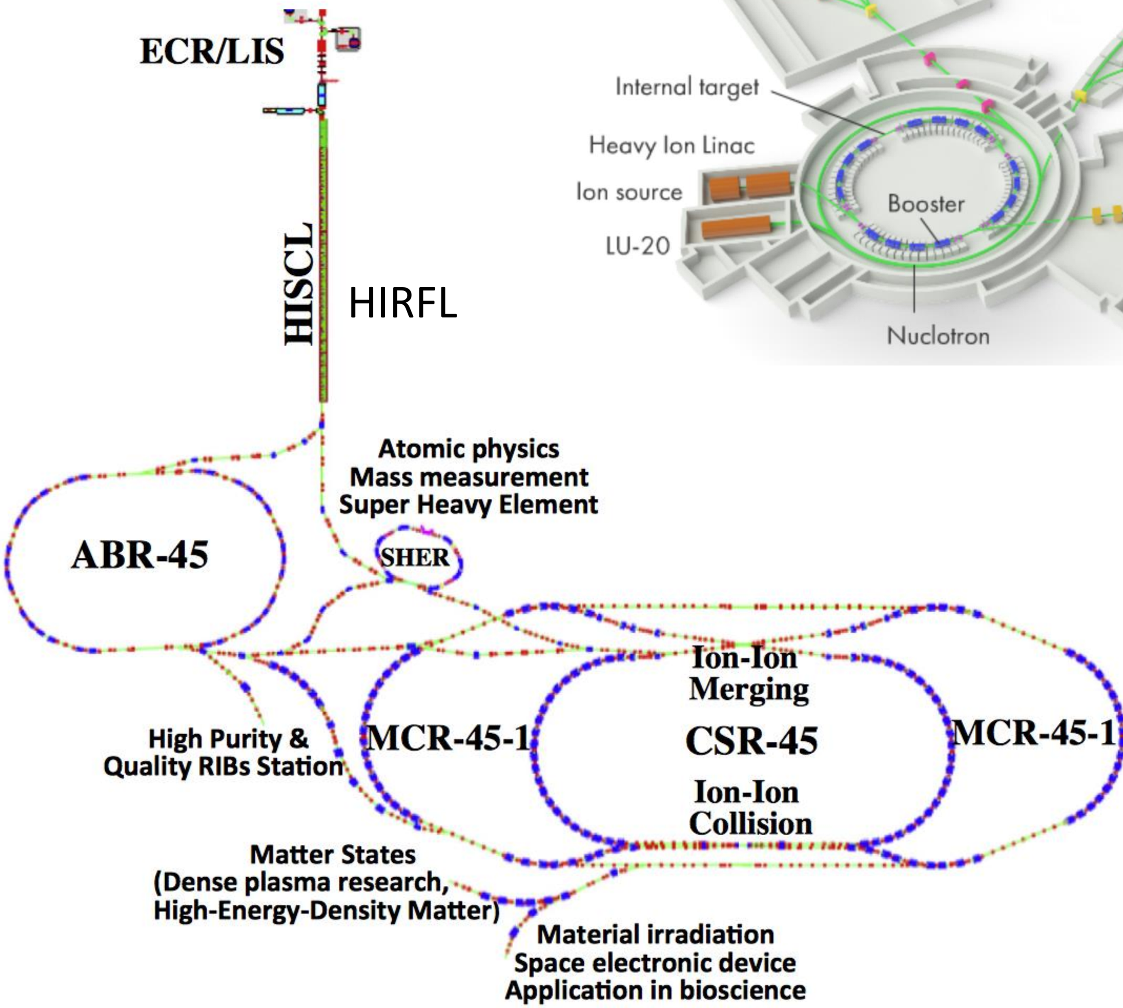

| Param. @ LHC collision | Nominal[1] 25 ns | Today * 50 ns | HL-LHC[1] 25 ns | HL-LHC[1] 50 ns |
|---|---|---|---|---|
| Int/bunch | 1.15E11 | ~1.6E11 | 2.2E11 | 3.5E11 |
| Bunches | 2808 | 1374 | 2808 | 1404 |
| Beam current [A] | 0.58 | | 1.12 | 0.89 |
| $\varepsilon_n$[μm] | 3.75 | ~ 2.4 | 2.5 | 3.0 |
| β*[m] | 0.55 | 0.6 | 0.15 | 0.15 |
| Peak Lumi [$cm^{-2}$ $s^{-1}$] | 1 $10^{34}$ | 7.74 $10^{33}$ | 9 $10^{34}$ | 9 $10^{34}$ |

- Nominal tune in “resonance free” region
- Tune spread necktie from space charge extends by ~0.30 in the vertical plane for LHC beams
- Spread fits tightly between integer resonance and 6.25 structure resonance



# NICA Complex



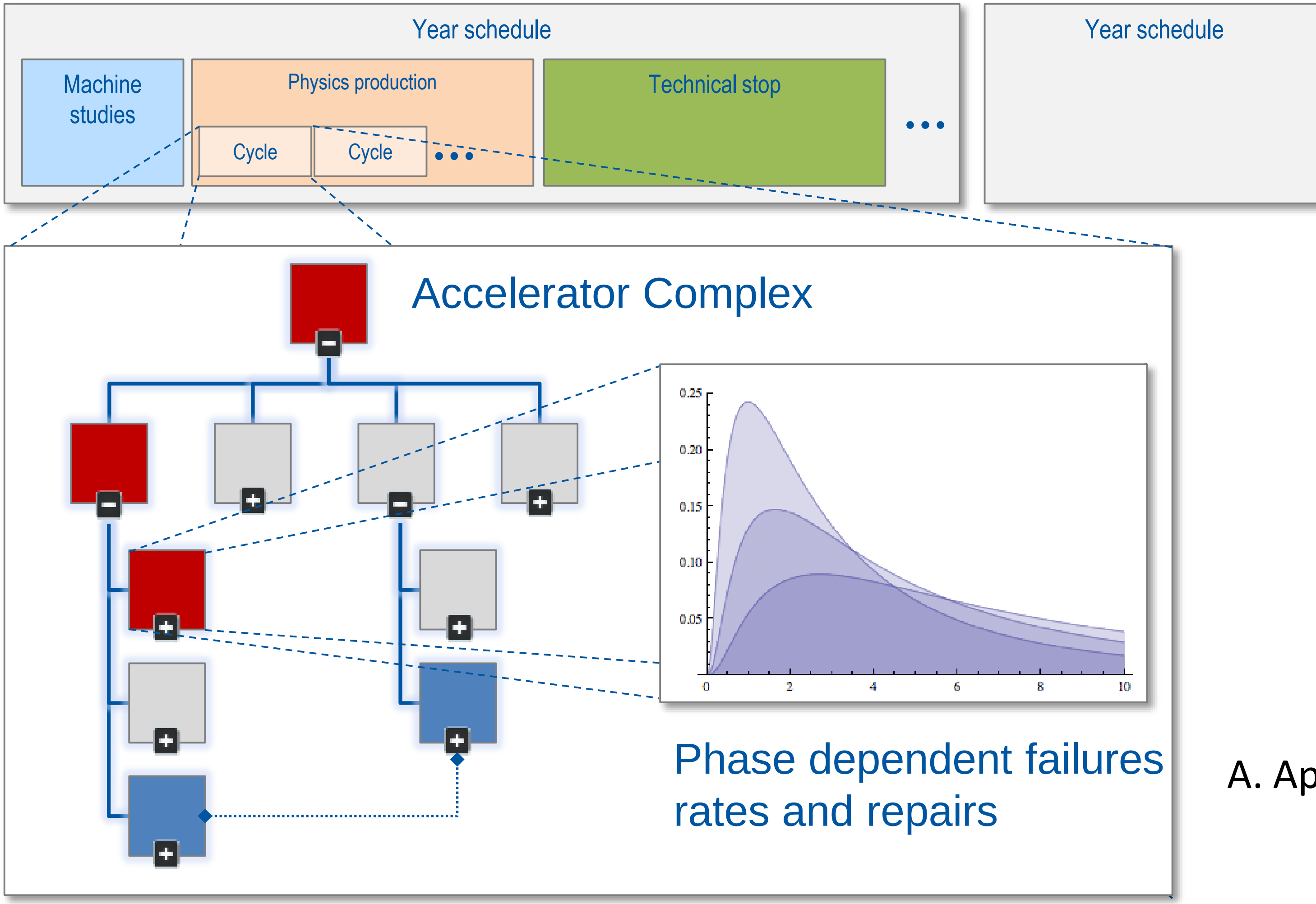



**Task 6.3. Reliability and Availability of Particle Accelerators (CERN, HIT)**

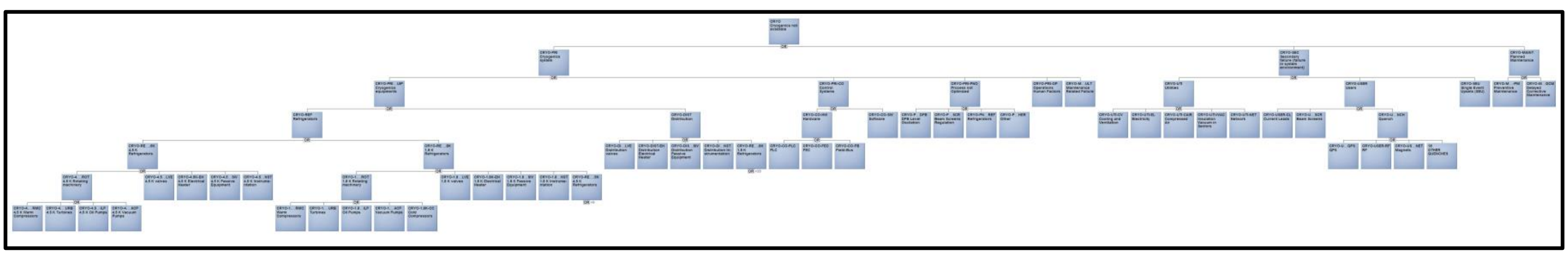
Highly reliable operation becomes ever more critical for future energy-frontier machines as well as many applications (e.g. accelerator-driven systems, hadron therapy). Through workshops and expert discussions the network will at first compile Reliability, Availability, Maintainability, Serviceability (RAMS) methods and practices at major and representative particle-accelerator facilities, create an inventory, and apply some ranking. Further analysis will then allow defining an optimal RAMS characteristics for particle accelerator systems. The identified best RAMS practices will be communicated to the partner institutes as well as to the entire accelerator community in order to introduce a common RAMS baseline. The feasibility of an Open Data Infrastructure for accelerator reliability will be assessed through topical workshops and expert exchanges.

- Establish standard body of RAMS knowledge for particle accelerator application
- Compile and rank existing RAMS standards, methods and practices in major laboratories
- Analysis of optimal RAMS characteristics for particle accelerator systems
- Spreading the identified best RAMS practices in order to introduce a common baseline
- Assess the feasibility of an Open Data Infrastructure for accelerator reliability

# Modelling Concept




A. Apollonio

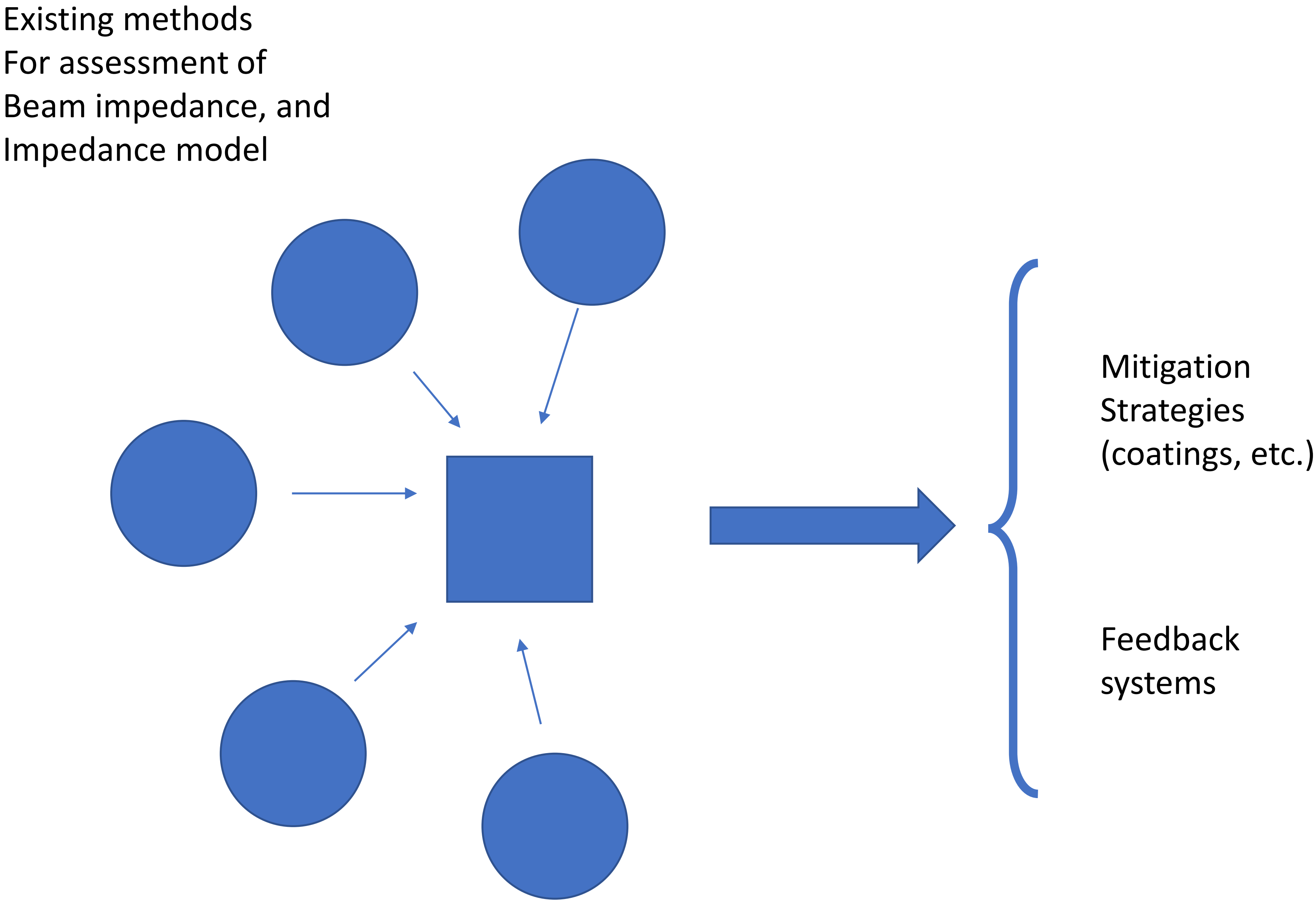


| Task sub-steps | Difficulty | Requirement |
| --- | --- | --- |
| Establish standard body of RAMS knowledge for particle accelerator application | 10 | global |
| Compile and rank existing RAMS standards, methods and practices in major laboratories | 10 | global |
| Analysis of optimal RAMS characteristics for particle accelerator systems | 10 | global |
| Spreading the identified best RAMS practices in order to introduce a common baseline | 11 | Global (reputation) |
| Assess the feasibility of an Open Data Infrastructure for accelerator reliability | 9 | Interdisciplinary |

**Task 6.4. Improved Beam Stabilization (INFN)**

Charged particle beams can become unstable due to an electro-magnetic interaction of the beam with vacuum-chamber resistivity and discontinuities, characterized in terms of machine impedance, or due to an interaction with an electron cloud building up inside the vacuum chamber. This networking task will compile and review the existing strategies and methods for beam-impedance assessments and impedance models. Through expert discussions and with the help of a dedicated post-doc student, it will review and propose novel methods to reduce accelerator impedance, such as special coatings. The task will also identify or develop strategies for electron-cloud mitigation at future accelerators. If the impedance or electron cloud cannot fully be suppressed, feedback systems are needed for beam stability. The task will also work on a conceptual design of advanced beam feedback systems for future machines. A workshop gathering experts on the electromagnetic interaction between a particle beam and its surrounding environment will review the activities and progress in theory, simulations, bench and beam-based measurements.

- Review existing strategies & methods for beam-impedance assessments and impedance models
- Propose and evaluate novel methods to reduce accelerator impedance
- Identify or develop strategies for electron-cloud mitigation at future accelerators
- Conceptual design of advanced beam feedback systems for future machines


Existing methods
For assessment of
Beam impedance, and
Impedance model
Mitigation
Strategies
(coatings, etc.)
Feedback
systems

**Task 6.5. Beam Quality Control in Linacs and Energy Recovery Linacs (JGU)**

There have been no multi-pass energy recovery linacs in operation yet, while several are being proposed or under construction, especially in Europe (MESA, LHeC, BerlinPRO). This task will organize joint workshops involving future Energy Recovery Linacs (ERL) projects and operating or soon-to-be-commissioned linacs/recirculating linacs and ERLs in Europe in order to develop synergies. A parameter database for the various facilities will be compiled. Innovative and alternative ERL approaches, e.g. ones involving FFAG arcs, will be explored through a topical workshop. Synergies between linac developers and source developers for optimum beam quality will be worked out in one or two other major workshops of this task, possibly covering electron linacs as well as proton linacs. Based on the results of the networking events a set of prioritized R&D guidelines will be formulated.

**Task 6.5. Beam Quality Control in Linacs and Energy Recovery Linacs**

- Expand synergies between proposed future ERL projects and operating or soon-to-be-commissioned linacs/recirculating linacs and ERLs in Europe
- Establish a parameter database for the various facilities
- Examine innovative and alternative ERL approaches
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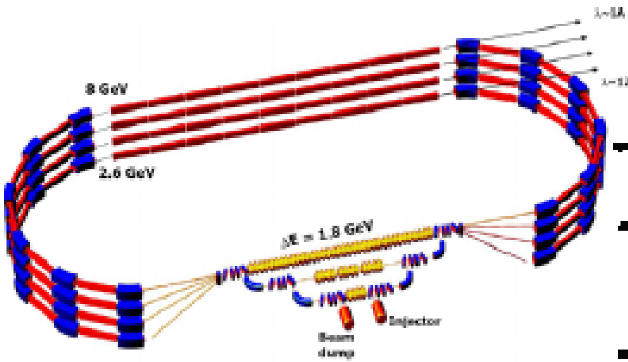
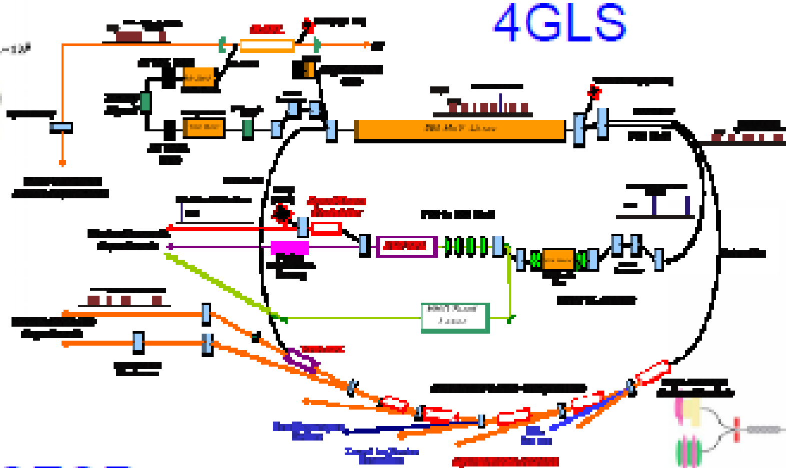
## BINP MARS

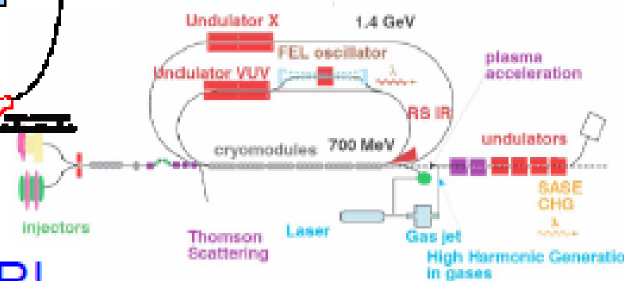



## 4GLS

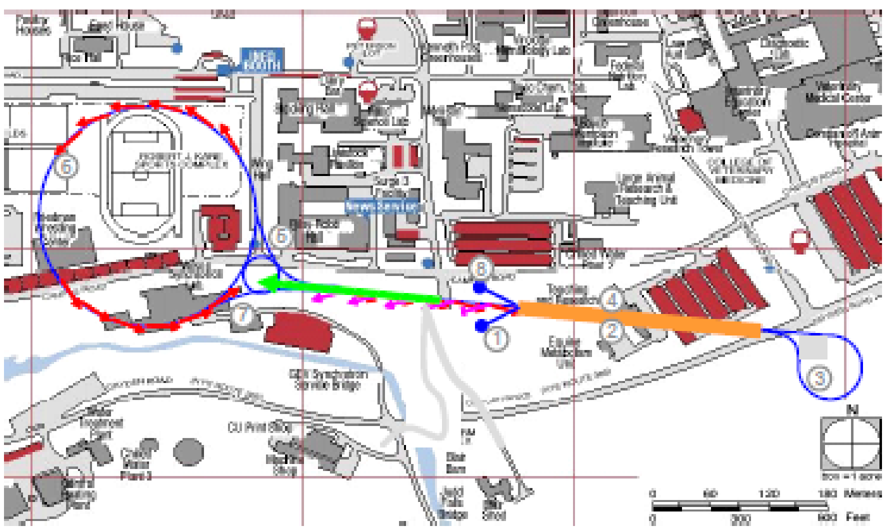


## ARC-EN-CIEL

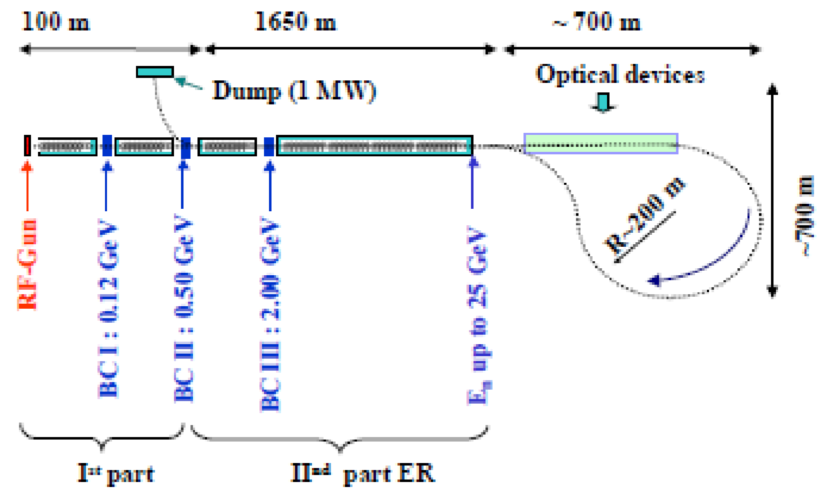
(ARC-EN-CIEL: Accelerator-Radiation Complex for ENhanced Coherent Intense Extended Light)




## ERL@CESR

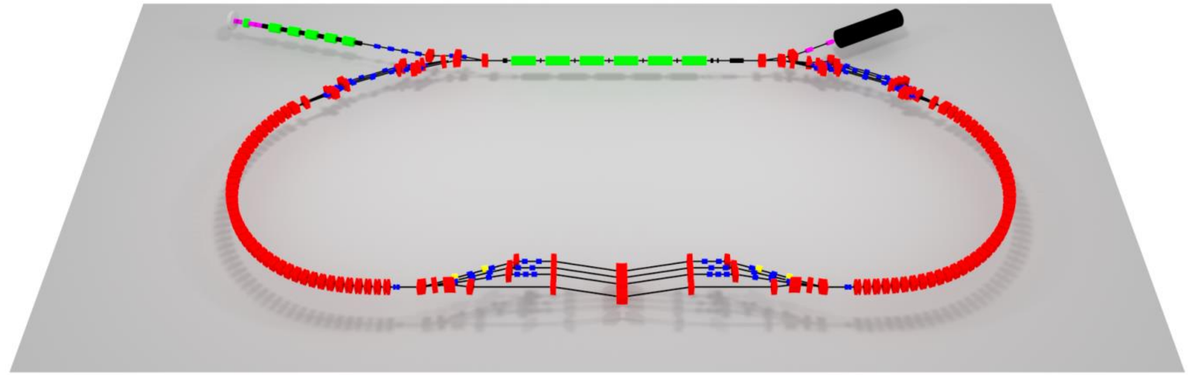


## XFEL ERL

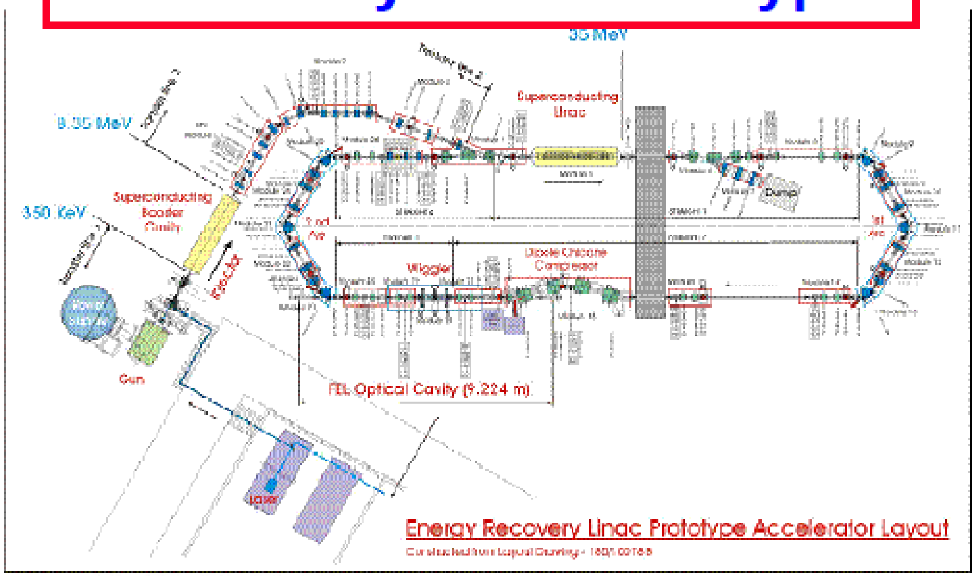



L Merminga, FEL 2005

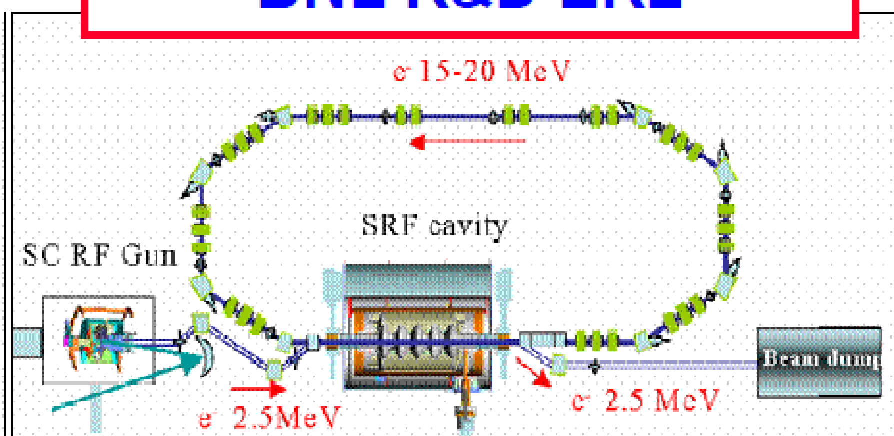

CBETA @ Cornell (FFAG Demonstrator):



Daresbury ERL Prototype




BNL R&D ERL



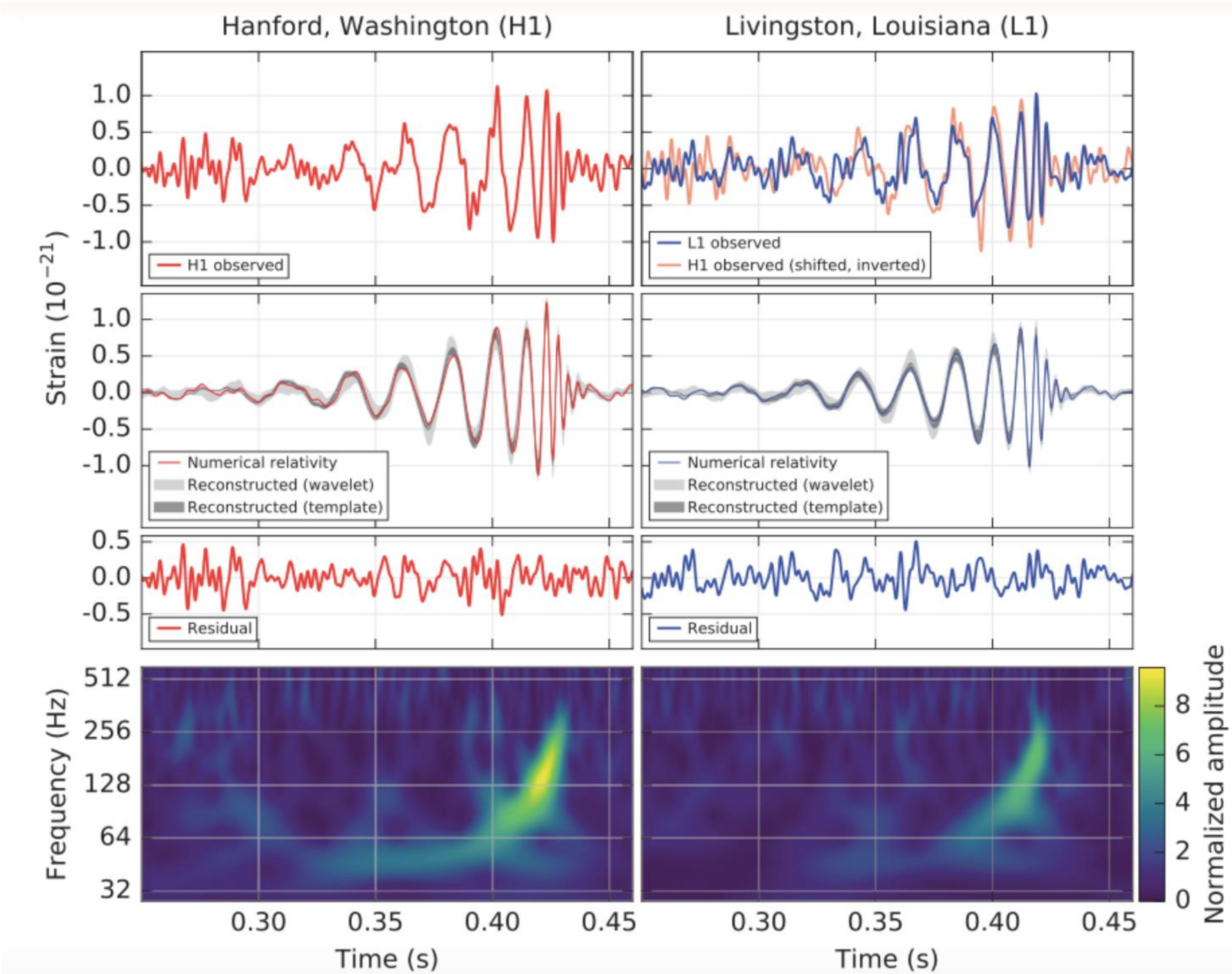

L Merminga, FEL 2005

F. Hug

**Task 6.6: Far Future Concepts & Feasibility (CERN, INFN)**

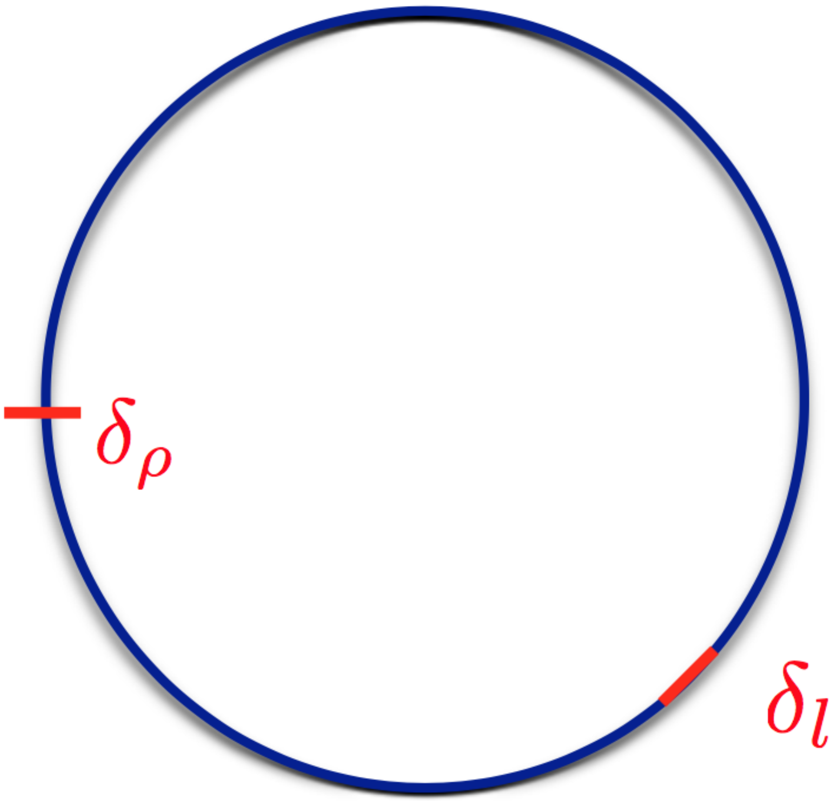
This task will organize or co-organize at least four specific workshops on (1) crystal applications for bending and acceleration, (2) advanced photon colliders, including gamma-gamma and photon-nucleon colliders, (3) advanced muon-collider concepts especially ones without ionization cooling, and (4) the potential use of large storage rings for gravitational wave detection or generation. This task is breaking new grounds. A dedicated PhD student will contribute exploratory studies on some of the aforementioned topics, including advanced muon collider concepts and gravitational waves at large hadron storage rings. A final workshop will help assessing and ranking a basket of future concepts with regard to “future feasibility” and physics cases, and prepare for the final deliverable, that is a white list of ranked future options.

- Analysis of the potential of crystals for charged-particle bending or particle acceleration
- Development of advanced photon colliders, including gamma-gamma and photon-nucleon colliders
- Assessment of advanced muon-collider concepts without ionization cooling
- Assessment of the potential use of large storage rings for gravitational wave detection or generation
- Assessing and ranking a basket of future concepts with regard to “future feasibility” and physics cases
- White list of ranked future options



Hanford, Washington (H1)
Livingston, Louisiana (L1)
H1 observed
L1 observed
H1 observed (shifted, inverted)
Strain ($10^{-21}$)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Frequency (Hz)
Normalized amplitude
Time (s)

Derivation of the longitudinal equations from first principles, is a Taks of 6.6

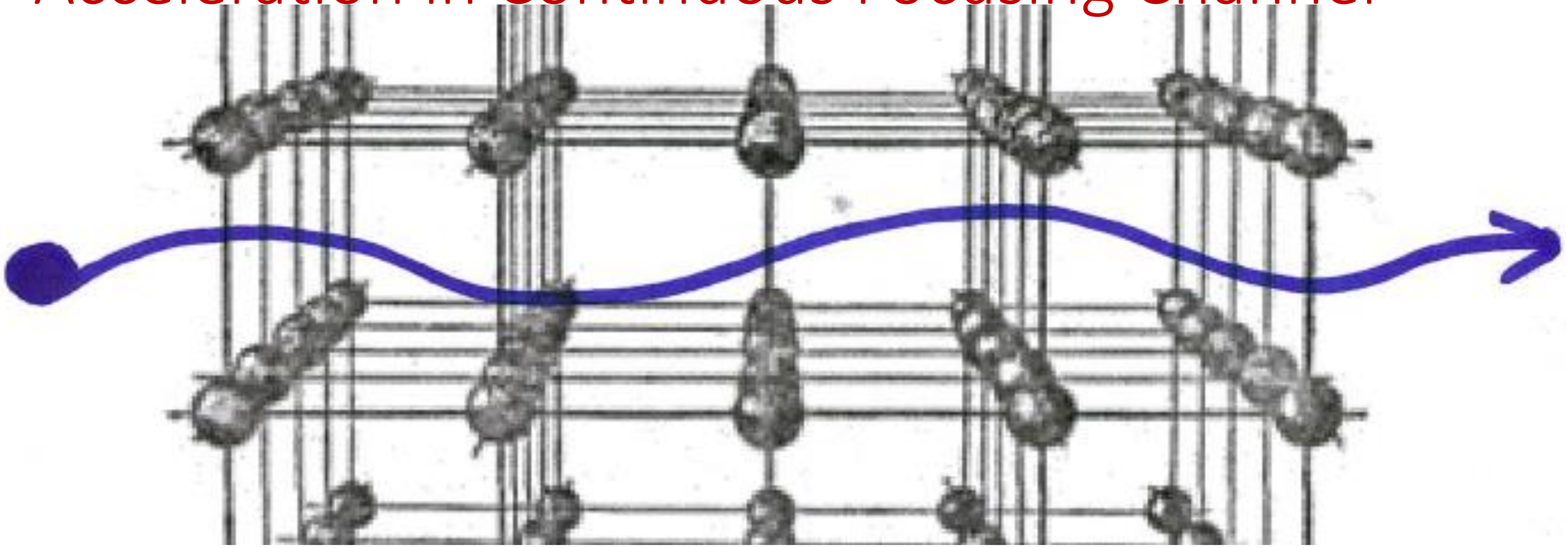


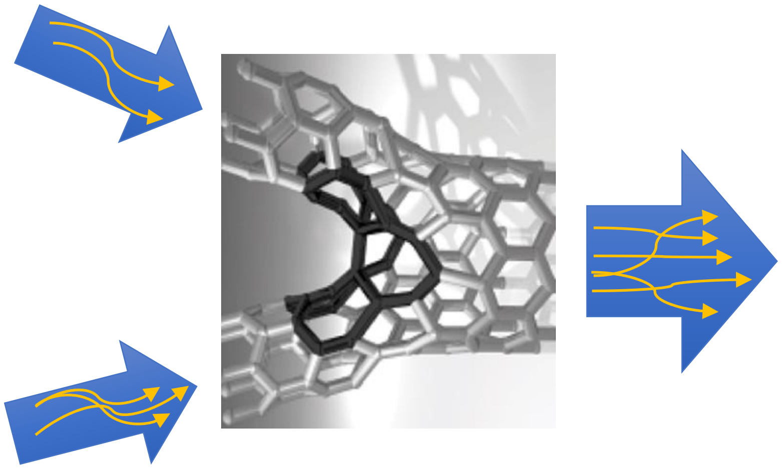

$$\ddot{\delta}_l + \omega_l^2 \delta_l = \omega_g^2 L f(\omega_g t)$$

$$\ddot{\delta}_\rho + \omega_\rho^2 \delta_\rho = \omega_g^2 \rho h(\omega_g, \omega_0, t)$$

# Crystal accelerators

Acceleration in Continuous Focusing Channel





Funneling with crystals

V. Shiltsev

# Deliverables

D6.1 : Ranking of performance degrading mechanisms for hadron storage rings and synchrotrons [28]. Compilation and classification of the processes causing performance degradation in past, existing and planned facilities **(Task 6.2)**

D6.2 : Report on optimal RAMS characteristics for particle accelerators [36]. Compilation of a list of Reliability, Availability, Maintainability and Serviceability (RAMS) methods and practices in different laboratories and definition of optimal RAMS characteristics for particle accelerator systems **(Task 6.3)**

D6.3 : Summary of novel methods to reduce accelerator impedance [36]. Compilation and review of existing strategies and methods for beam-impedance assessments and impedance models **(Task 6.4)**

D6.4 : Report on outstanding open questions and prioritized R&D guidelines for Energy Recovery Linacs [44]. Compilation of a parameter database for various facilities including innovative and alternative Energy Recovery Linacs (ERL) approaches. Formulation of guidelines for the design of ERLs **(Task 6.5)**

D6.5 : White list of ranked far-future accelerator options [46]. Assessment and ranking of several future concepts with regard to “future feasibility” and physics cases, including a summary report **(Task 6.6)**

# Welcome to

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