HORIZON 2020

Accelerator Performance and Concepts report from WP6

http://aries.web.cern.ch/content/wp6

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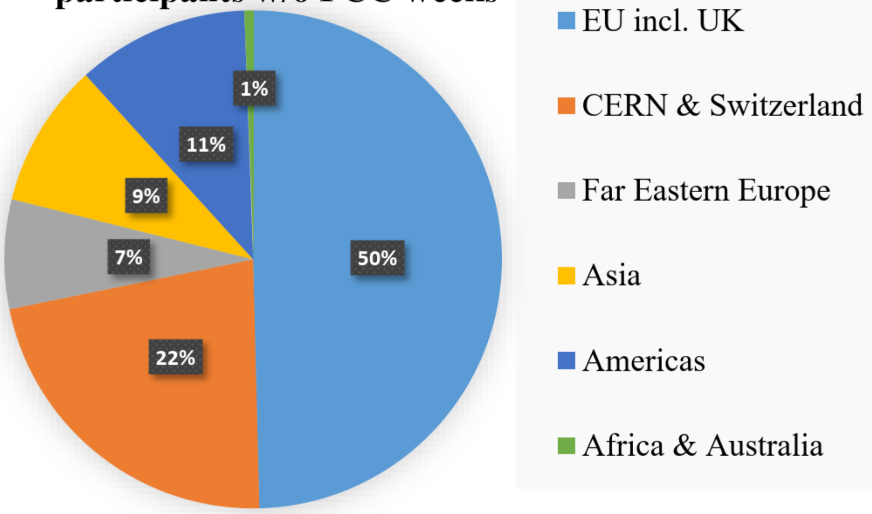
ARIES Annual Meeting

CERN, 21 April 2021

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

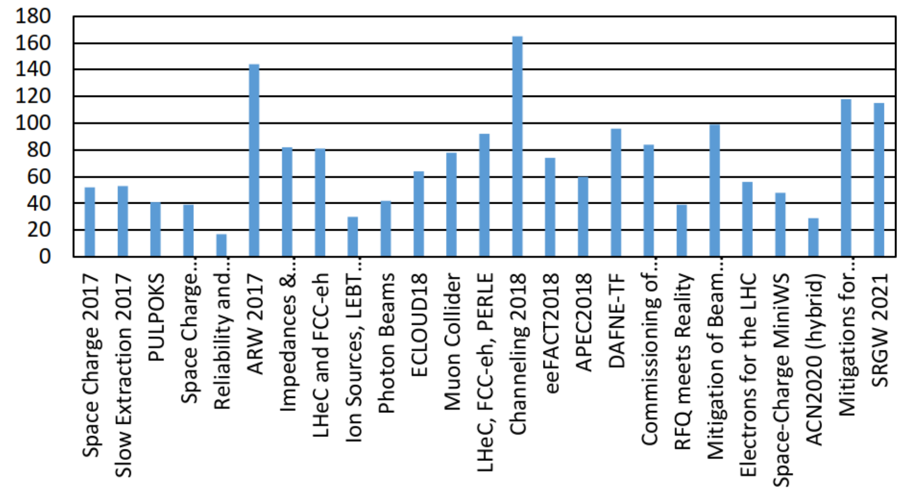
ARIES WP6 workshops

geographic distribution of WP6 workshop participants w/o FCC weeks

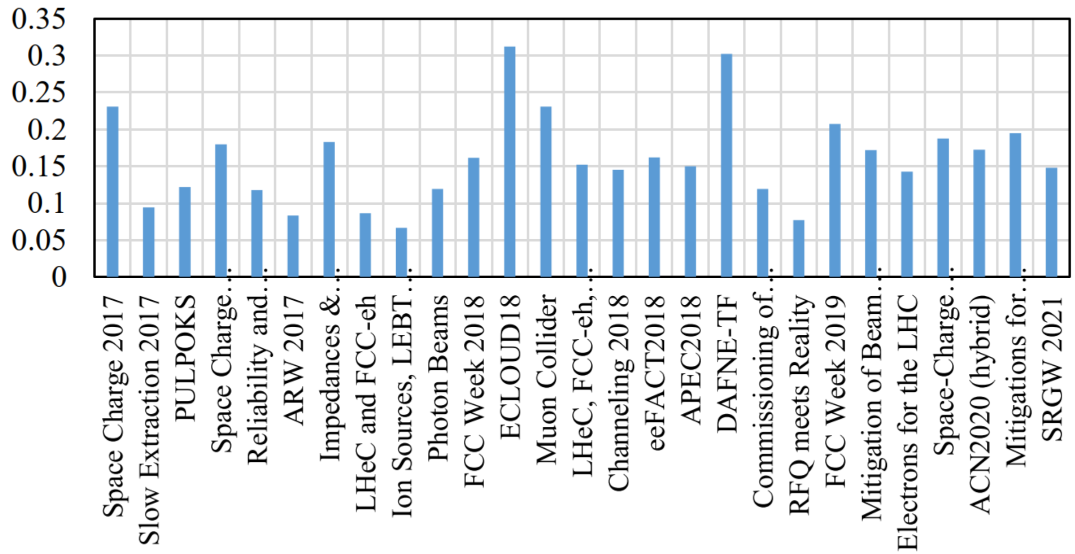


1798 (914) participants with (without) FCC Weeks

total number of participants w/o FCC weeks



fraction of woman participants in ARIES WP6 workshops



fraction of women participants in all WP6 workshops

27 WP6 workshops in total

recent ARIES WP6 milestones and deliverables

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
MILESTONE REPORT
Report on 2nd Annual Workshops of all WP6 APEC Tasks
MILESTONE: MS27
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
DELIVERABLE REPORT
Ranking of performance degrading mechanisms for hadron storage rings and synchrotrons (M28)
DELIVERABLE: D6.1
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
MILESTONE REPORT
Report on Parameter Database for Various ERL & Linac Facilities
MILESTONE: MS28
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
DELIVERABLE REPORT
Report on optimal RAMS characteristics for particle accelerators
DELIVERABLE: D6.2
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
MILESTONE REPORT
Report on 3rd Annual Workshops of all WP6 APEC Tasks
MILESTONE: MS29
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
DELIVERABLE REPORT
Summary of novel methods to reduce or mitigate accelerator impedance (M36)
DELIVERABLE: D6.3
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
MILESTONE REPORT
Report on Strategies for electron-cloud mitigation in future accelerators
MILESTONE: MS30
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA
MILESTONE REPORT
Identification & prioritization of mitigation approaches
MILESTONE: MS31
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
MILESTONE REPORT
Feasibility of an Open Data Infrastructure for accelerator reliability
MILESTONE: MS32
approved

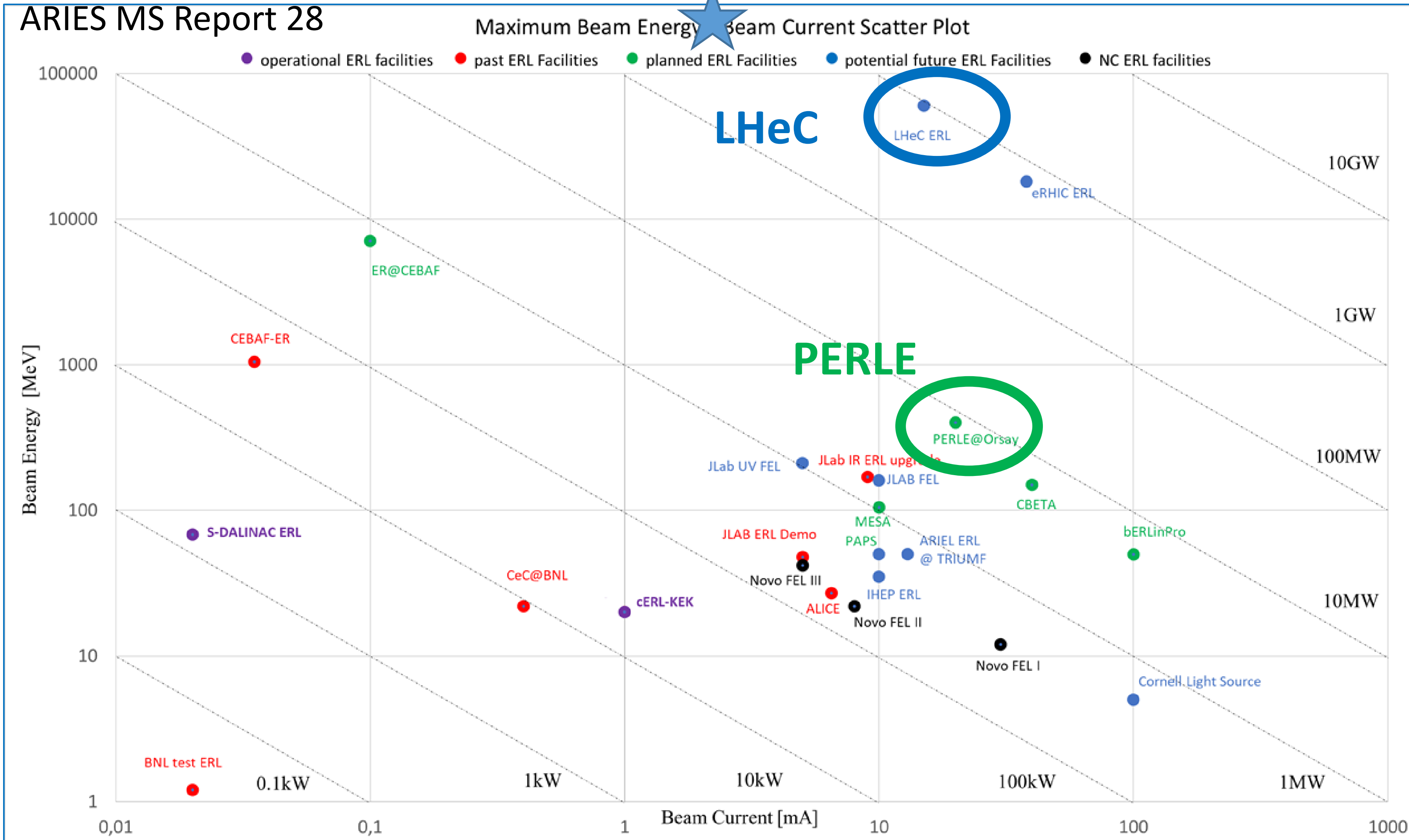
ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
DELIVERABLE REPORT
Outstanding open questions and prioritized R&D guidelines for Energy Recovery Linacs
DELIVERABLE: D6.4
approved

ARIES
Accelerator Research and Innovation for European Science and Society
Horizon 2020 Research Infrastructures GA n° 730871
DELIVERABLE REPORT
White List of Ranked Far-Future Accelerator Options
DELIVERABLE: D6.5
approved

ERL landscape

FCC-ee-ERL

ARIES MS Report 28



LHeC/FCC-eh Workshop, CERN, Switzerland, 11-13 September 2017

LHeC, FCC-eh, and PERLE Workshop, LAL Orsay, France, 27-29 June, 2018

Electrons for the LHC, Chavannes-de-Bogis, Switzerland, 24-25 October 2019

F. Hug

ARIES MS28

recent HORIZON 2020 ARIES WP6 workshops

1. **Accelerator Applications of Crystals and Nanotubes,** EPFL Lausanne, 10-11 March 2020

2. **Mitigation Approaches for Hadron Storage Rings and Synchrotrons (Mitigations2020),** safe virtual space, 22 June – 1 July 2020

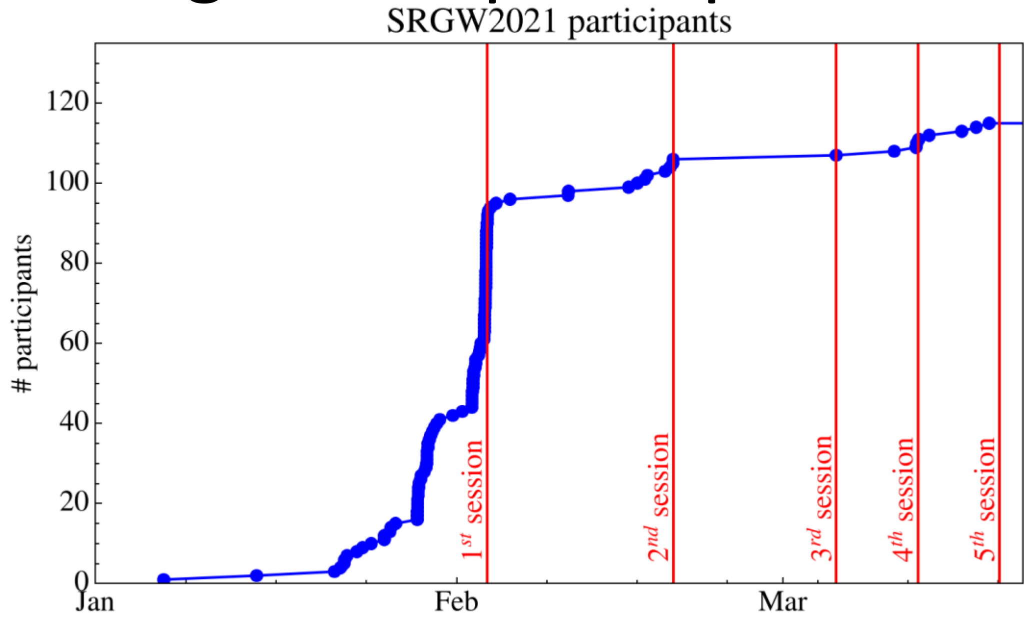
3. **ARIES Workshop on Storage Rings and Gravitational Waves (SRGW2021),** safe virtual space, 2 February -18 March 2021

ARIES Workshop on Storage Rings and Gravitational Waves (SRGW2021), virtual space, 2 February -18 March 2021 ; chaired by G. Franchetti, Marco Zanetti, and F. Zimmermann

Scientific Programme Committee

William A. Barletta	MIT
Pisin Chen	NTU
Raffaele-Tito D'Agnolo	IPHT
Raffaele Flaminio	LAPP
Giuliano Franchetti (co-chair)	GSI
Shyh-Yuan Lee	Indiana U
Katsunobu Oide	CERN & KEK
Qing Qin	ESRF & U. Peking
Jorg Wenninger	CERN
Marco Zanetti (co-chair)	U. Padova
Frank Zimmermann (co-chair)	CERN

115 registered participants

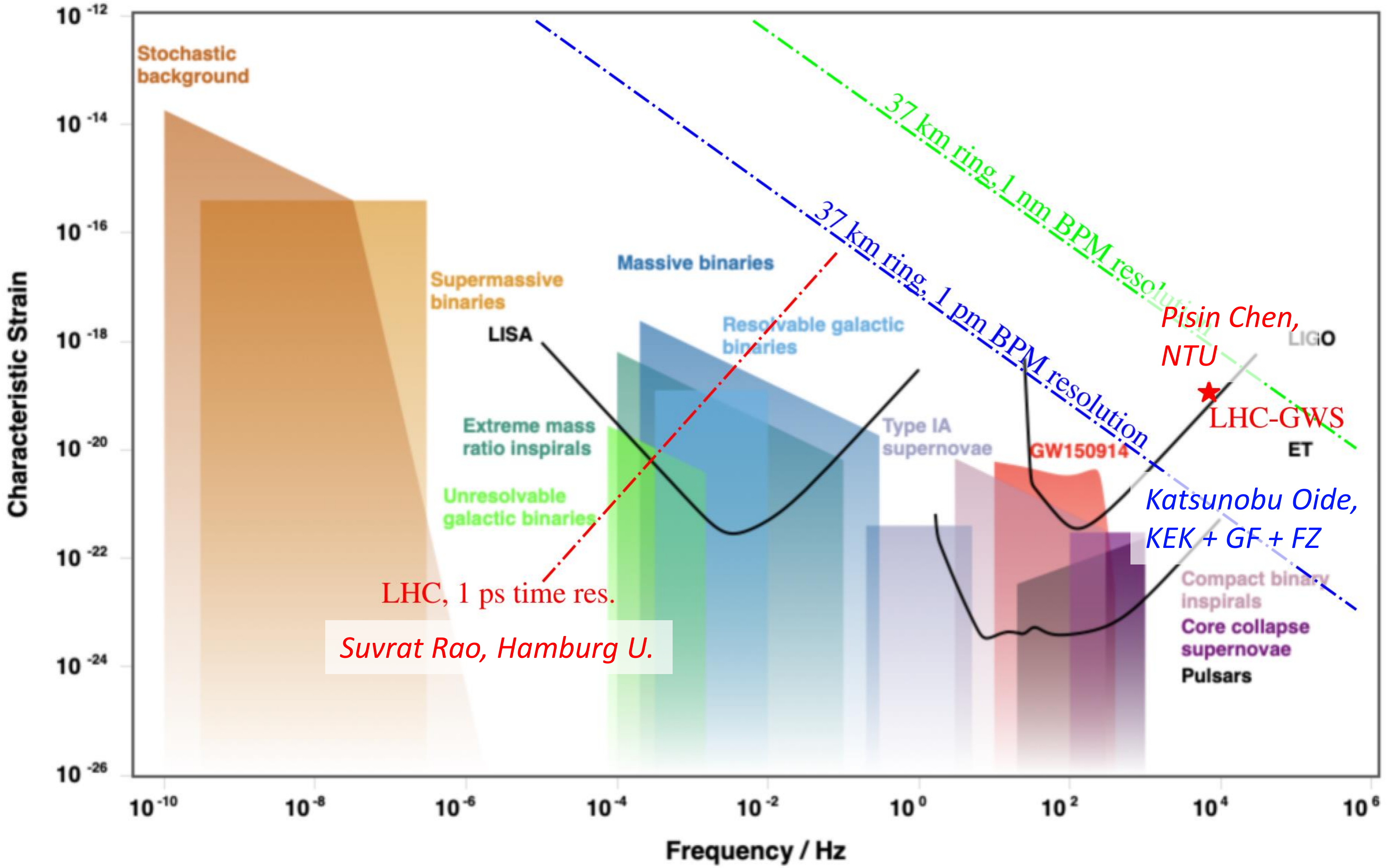


main focus: detection and/or generation of gravitational waves or other gravity effects using storage rings & accelerator technologies

Sessions:

2/2/2021, **Introduction to Gravitational Waves and their effects,** chair: *Pisin Chen / NTU Taiwan*
18/2/2021, **Measurements and sensitivity,** chair**:** *Shyh-Yuan Lee / Indiana U*
4/3/2021, **Proposals and Schemes**, chair*: Jörg Wenninger / CERN*
11/3/2021, **Gravitational wave generation and detection,** chair: *Frank Zimmermann / CERN*
18/3/2021, **Ground motion and final discussion,** chairs: *Giuliano Franchetti/GSI; John Ellis/CERN*

Detection (& Generation) Plot emerging from SRGW2021



G. Franchetti et al.

Ranking of performance degrading mechanisms for hadron storage rings and synchrotrons

Summary of the accelerator characteristics and main beam features at the laboratories participating in the ARIES ranking effort

Laboratory	Accelerator name	Accelerator Circumference (m)	Initial/final Energy (GeV)	Particles per bunch	Rms bunch length (cm)	Ramp time (s)/ stored time (s)
Fermilab	Booster	476	0.4/8	5E10	30	0.033
BNL	RHIC	3834	25/255	2E11	0.6	300/3600
CERN	SPS	7000	26/450	1.1E11	15	5/20
SLAC/SSRL	SPEAR3	234	3	8.7E9	0.6	NA
J-PARC	Main ring	1567.5	3/30	3.3E13	1500	1.4/0~2
INFN-LNF	DAFNE	97	510	1E11	1.06	0/1200
GSI	ESR	108	0.4/0.004	1E8	200	10/2000
GSI	SIS18/SIS100	216/1000	0.011/2.7	5E11	3000	0.5

End 2018, APEC2018 workshop

ARIES D6.1

Ranking results on performance degrading mechanisms for hadron storage rings and synchrotrons

ARIES D6.1

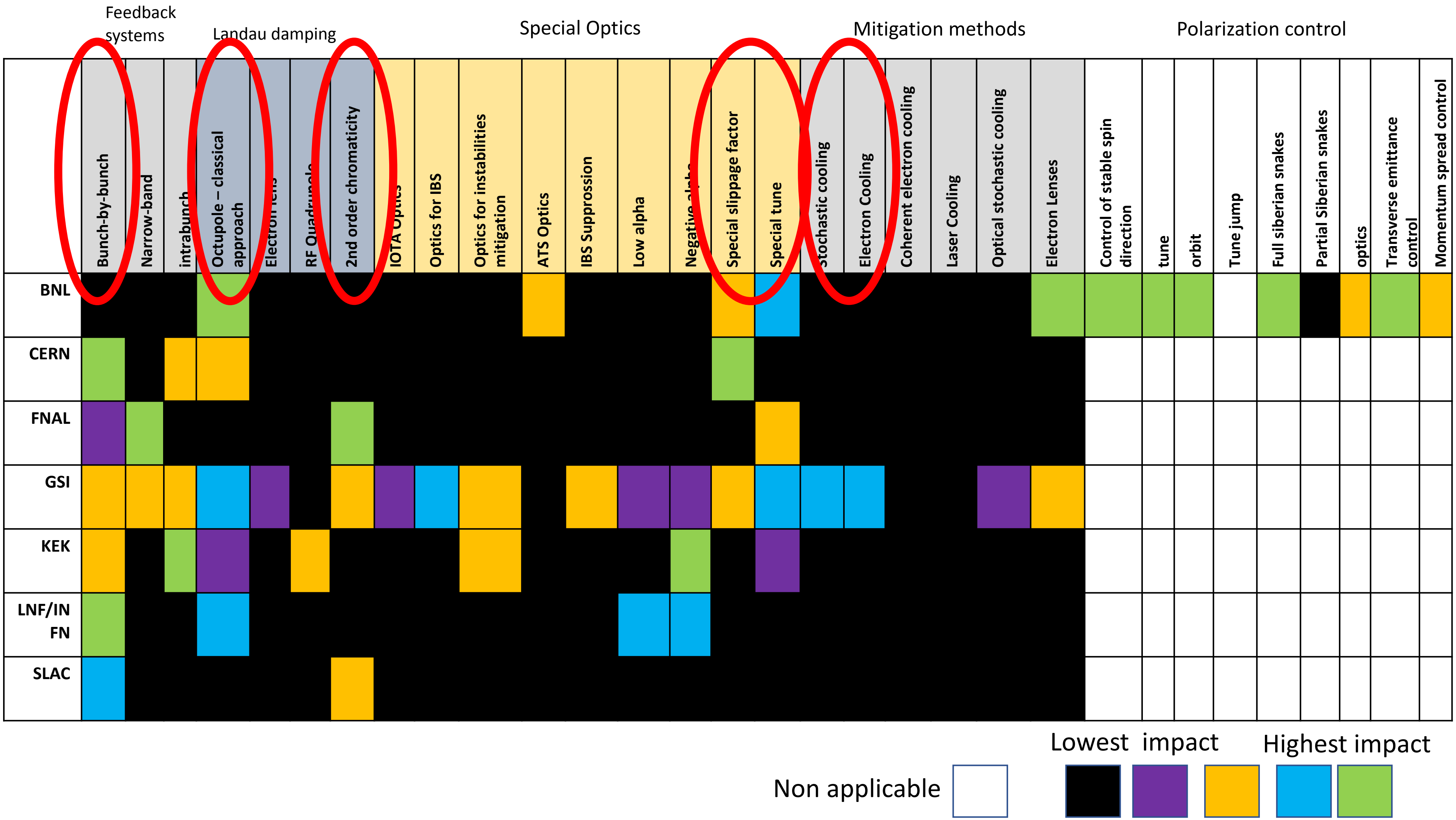
R	Intensity limitation	ave	std
1	Beam loss	3.12	1.16
2	RF Power	2.75	1.2
3	Single bunch instability	2.75	0.82
4	Multi-bunch instability	2.75	1.56
5	Injector	2.6	1.6
6	DA	2.375	0.99
7	Collimation	2.25	1.09
8	Momentum Acceptance	2.25	1.2
9	E-Cloud	2.25	1.3

R	Brightness limitation	ave	std
1	Nonlinearities	3.625	0.99
2	Space charge	3.125	1.53
3	Beta-beating	2.5	1.3
4	Injector	2.5	1.75
5	Beam-beam	2.0	1.41
6	IBS	1.75	1.39

R	Other performance limitation	ave	std
1	Beam loss	3.37	1.21
2	Halo development	2.5	1.22
3	Collimation	2.37	1.21
4	Dynamic vacuum	2.37	1.4
5	Peak luminosity	2.12	1.53
6	Spill. Structure	2.0	1.73
7	Quenches	1.37	0.69
8	UFO/dust	1.12	0.33

End 2018, APEC2018 workshop

full mitigation ranking by laboratory



For FNAL the Fermilab booster is considered, for BNL the RHIC, for CERN SPS, for SLAC SPEAR III, for KEK the J-PARC Main Ring, for INFN-LNF DAΦNE, and for GSI the ESR, SIS18 and SIS100.

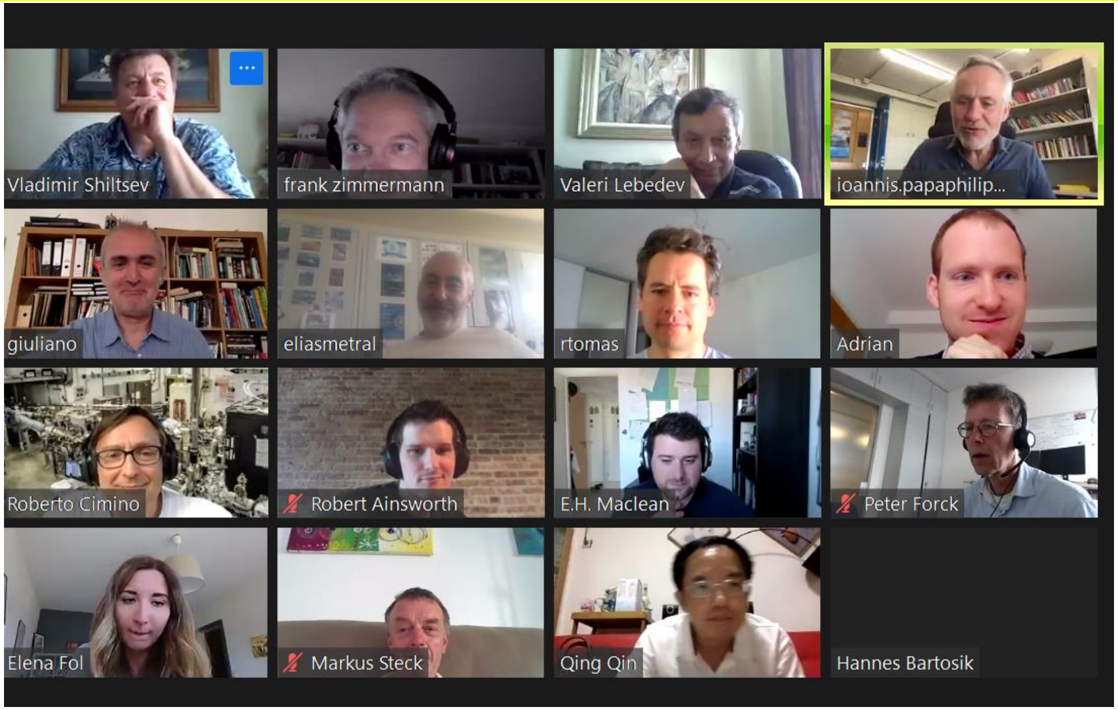
ARIES MS31

APEC2018 and Mitigations 2020 workshops

ARIES Mitigations workshop & Ranking for Space Charge Effects

ARIES MS31

Summer 2020



J-PARC Main Ring (MR) Fast Extraction (FX) operation: 1) **Injection beam optimization** with the Rapid Cycling Synchrotron (RCS) parameters; 2) RF operation with **2nd harmonic** and the **new feedback** system; 3) **Correction of the beta modulation and resonances**; 4) Transverse instabilities suppressed with **chromaticity settings & intra-bunch feedback systems**.

CSNS project - main strategies: **tune optimization** & proper **injection scheme**. Present limits are pushed through: 1) Installing **trim quadrupoles** to shape the tune curves; 2) Installing **AC sextupoles** to control the coherent oscillations; 2) **Re-installing injection components** to realize the real correlated painting scheme; 3) Re-sorting the dipoles according to the magnetic field measurement in AC mode

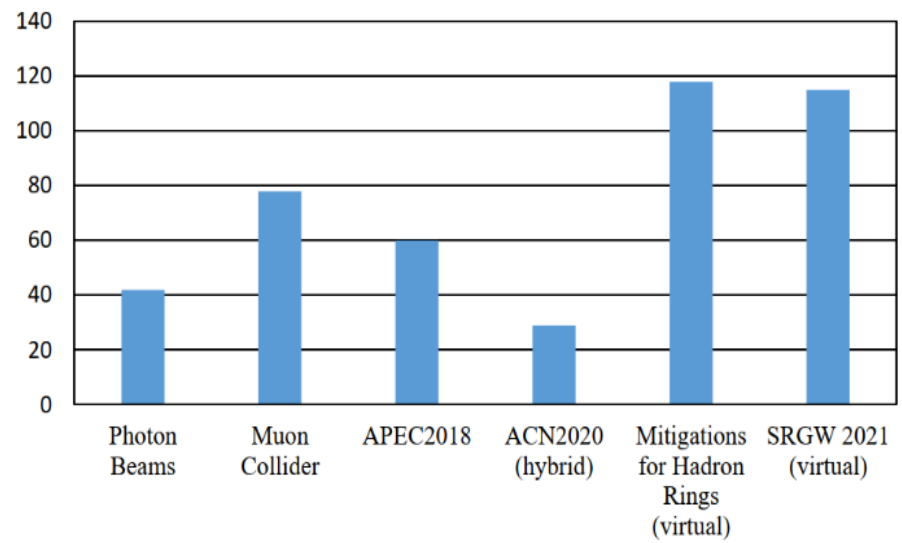
FNAL PIP II	Driving forces	**Near Term Mitigations**	**PIP-II Era Mitigations**
Emittance growth at injection	Space charge	Resonance (1/2) compens.	Higher inj. energy; Painting inj; Two-stage collimation
Longitudi nal losses at inj.	Adiab. Capt. ; Field stability	LLRF Upgr. ; Improved field stab.	Direct bucket injection w. chopping
Loss during transition	Instabilities; Emittance growth at inj.	Damper upgrades	Increased transition rate Reduced leakage
Extraction losses	Vert. Ap. restriction		Magnets w. larger aperture in ext. region

GSI: UNILAC upgrade measures: high intensity **RFQ, heavy ion stripping**, end-to-end optimization, etc.; SIS18: intensity limitation mechanism: **dynamic vacuum**, other beam instability mechanisms, etc; mitigation: **feedbacks**. Storage rings: **precision beam controls**.

For **RHIC and EIC-** some unique techniques: 1) **bright sources** (high-intensity H-, polarized H-, laser+EBIS); 2) **orbit/tune/coupling/ (chromaticity) feedbacks on ramps/in stores**, **transitions jumps** (in AGS, and in RHIC – a slowly ramping SC machine); 3) **beam-beam compensation with electron lenses**. Importantly, **beam cooling** fundamentally changes how RHIC is operated. Two cooling systems are operational (**stochastic cooling for high-energy ions; electron cooling for low-energy Au**), leading to much higher luminosity and cleaner operating conditions. A **novel strong hadron beam cooling scheme.**

final community survey on (far)-future options

The survey invitation was sent to 388 different participants from six ARIES exploratory workshops. In total 94 experts responded.



(Far-)Future Options for Survey

1. Energy Recovery (>50 GeV and/or > 50 mA)
2. Plasma Acceleration
3. Photon Collider
4. Gamma Factory
5. Muon Collider, positron based
6. Muon Collider, proton based
7. Crystal/Nanostructure Acceleration
8. Crystal Bending
9. Crystalline Beams
10. Gravitational Wave Detection using Storage Rings
11. Gravitational Wave Generation using Accelerators
12. High Energy Photon Generation using Entanglement and Moessbauer Effect
13. Non-electromagnetic acceleration or focusing mechanisms incl. gravity based schemes

ARIES survey criteria & choices

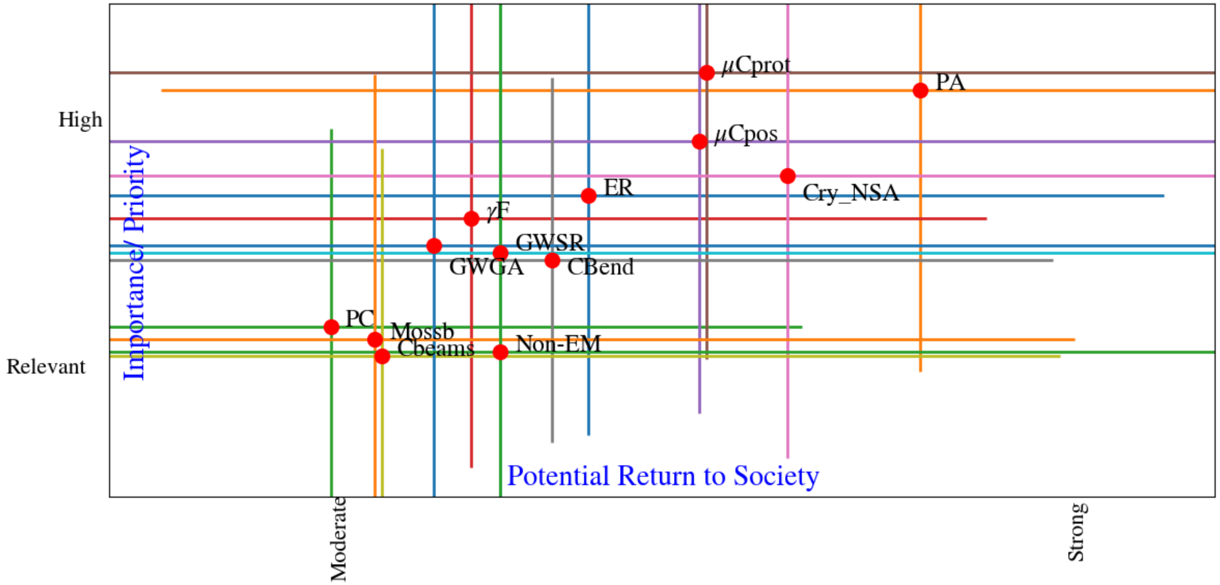
Feasibility	Importance/ Priority	Risk of Failure	Potential Return to Society	Time scale	Numeric ranking
Easy	Marginal	None	Negative	Next 5 years	1
Reachable	Relevant	Moderate	Marginal	Next 10 years	2
Difficult	High	High	Moderate	Next 20 years	3
Technically hard	Very high	Certain !	Strong	Next 40 years	4
Very challenging	Top		Game Changer !	Next 100 years	5
Impossible					6

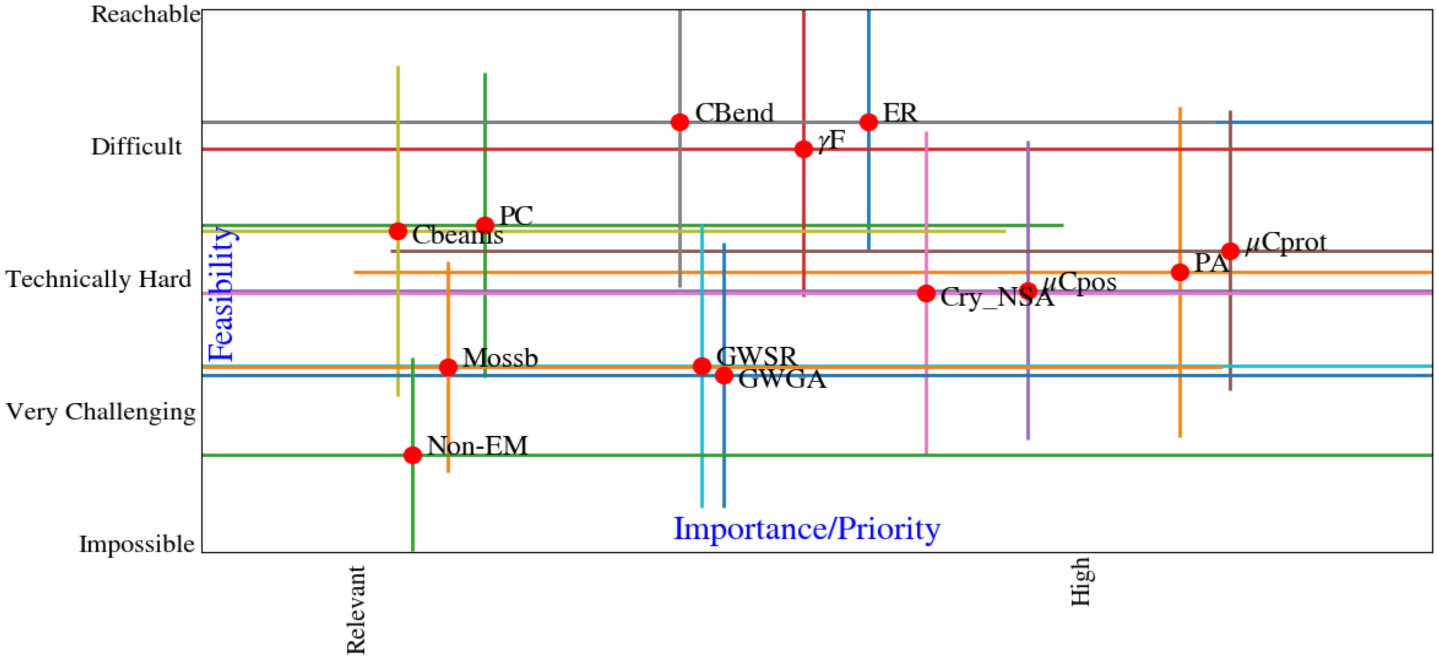
April 2021

survey results 1

April 2021

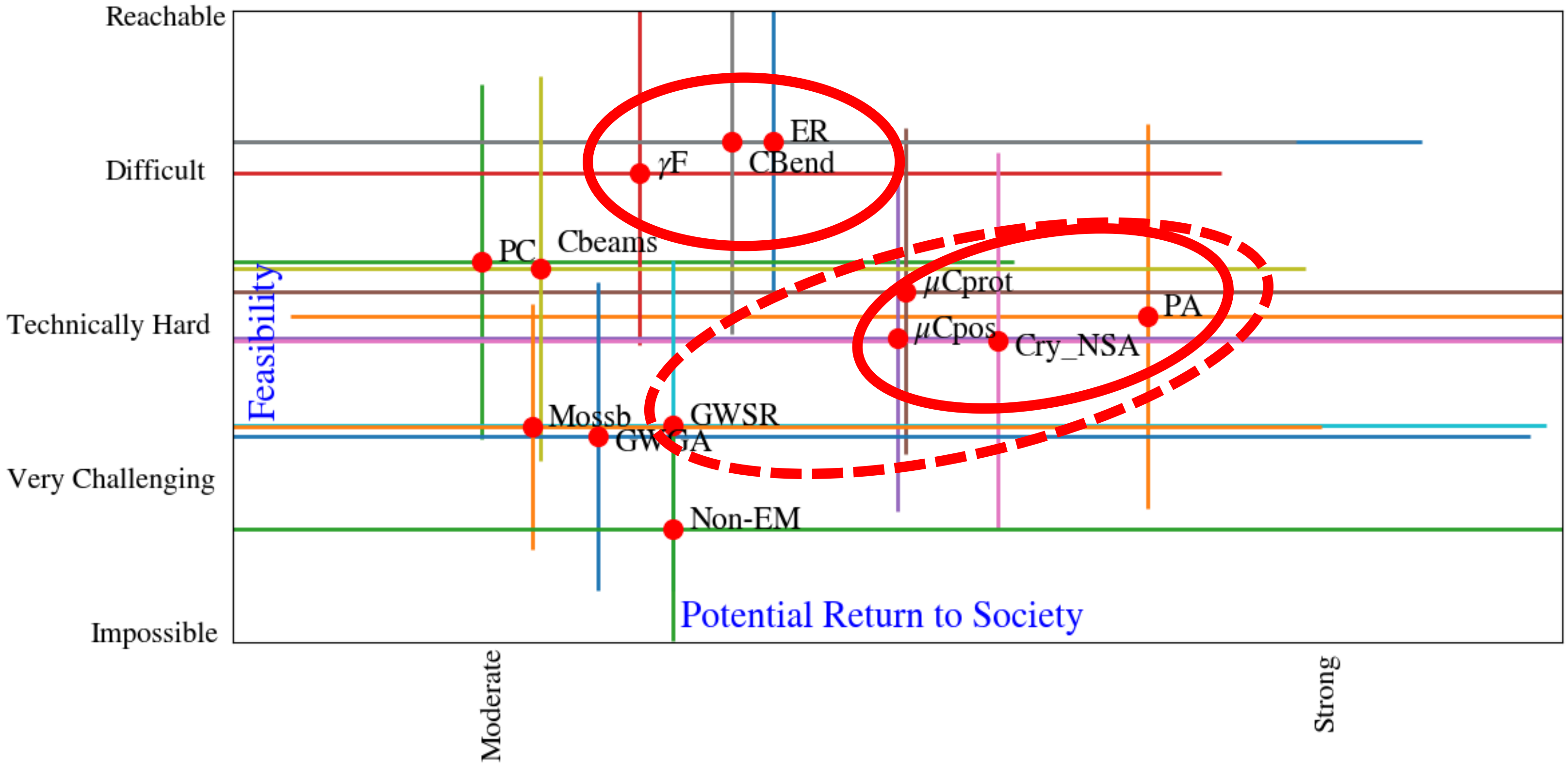
ARIES D6.5



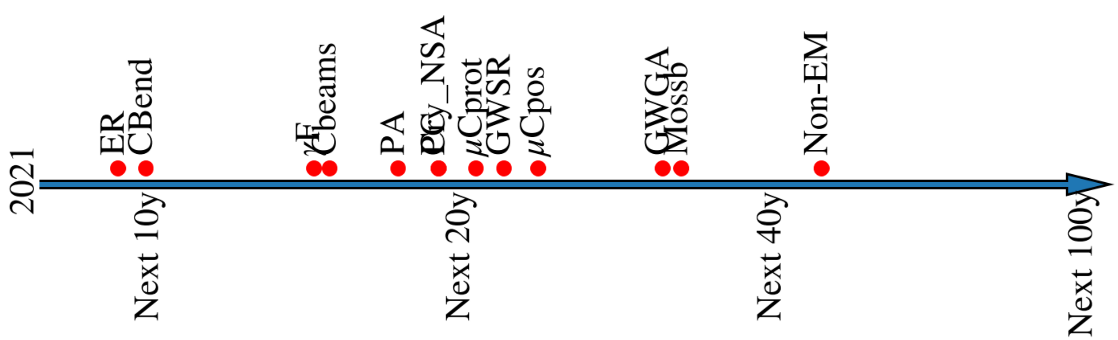


survey results 2

April 2021



Expected realization time scale



ARIES D6.5

White List of Ranked Far-Future Accelerator Options

April 2021

ARIES D6.5

Time scale	Priority and focus
10-15 years	Energy recovery Crystal bending Gamma Factory
15-30 years	Proton based muon collider Plasma acceleration Positron based muon collider Crystal and nanostructure acceleration Gravitational wave detection using storage rings
	Low or no priority
	Photon collider Crystalline beams "Moessbauer acceleration" using photon entanglement Gravitational wave generation using accelerators Non-electromagnetic acceleration or focusing mechanisms

key results from WP6 APEC

- **ERL R&D guidelines** [D6.4]

  (1) test facilities, (2) beam dynamics & diagnostics, (3) electron sources & injectors, (4) SRF: high loaded Q cavity operation; HOMs, HOM damping & high current operation; high Q_0 cavity performance

- **optimal RAMS characteristics for accelerators** [D6.2]

  availability critical systems and availability model (FCC-ee); measures to improve reliability of power converters, RF system, and electrical distribution (lead causes of unavailability for CERN's normal conducting machines); operations modelling platform (FCC-hh) for allocating availability goals to different sub-machines, fault-tolerant system design

- **performance limitations in hadron synchrotrons** [D6.1]

  beam loss, single-bunch instabilities, & nonlinearities prominent

- **mitigation measures** [MS31, D6.3]

  Landau octupoles, bunch-by-bunch feedback, optimised tunes, and tailored slippage factor; novel techniques emerging ; for Space Charge: reduced the peak intensity (CERN, PSB, JPARC),resonance compensation, optimized lattice & working point; future e-lenses ; Impedance: mechanical design optimization, feedback systems, advanced coatings (HTS,…)

- **ranking of (far-)future accelerator options** [D6.5]

  (1) **energy recovery linacs**, crystal bending, **Gamma Factory**
  (2) **muon collider(s),** plasma & **crystal & nanostr. acceleration, gravitational wave detection**