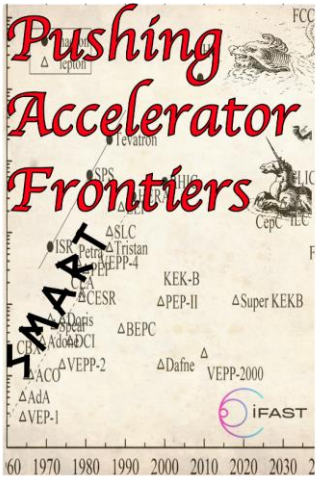


I.FAST 2nd Annual Meeting, 20.04.2023

Task 5.2 Pushing Accelerator Frontiers (PAF)

- **Main tools:** **topical workshops and dedicated prospective studies**
- **Overriding goal:** survey **accelerator frontiers and develop long-term strategies** for boosting the performance of **future facilities** and for **overcoming limitations;** develop a **coherent landscape for future accelerators and issue targeted R&D recommendations**

- **Thrust 1:** networking on **novel intense positron sources**, providing a **"condensation point" for the worldwide positron-source community** (**CNRS – Iryna Chaikovska**)

  - different methods of e^+ production, both classical techniques & especially novel/exotic ones

- **Thrust 2:** **survey extreme beams and ultimate limits**, and examine **approaches to overcome the present limits on beam brightness** (**CERN – Frank Zimmermann, GSI – Giuliano Franchetti**)

  - **space-charge compensation or cooling, crystalline beams,..** - ultimate limits on **high-gradient acceleration, high-field bending, beam size, beam density, and luminosity**

- **Thrust 3:** **artificial intelligence for accelerators,** applications of **machine learning, deep learning, advanced optimization algorithms and neural networks**, for accelerator control & design (**PSI – Rasmus Ischebeck**)
- **Thrust 4:** **accelerators for "dark sector" & precis. physics** (**CERN – Christian Carli, GSI – Bernd Lorentz**)

  - accelerator/beam requirements for dark-sector searches in fixed-target experiments; investigating current precision frontier accelerator developments, such as EDM ring designs

- **Thrust 5**: **green accelerators, sustainable accelerator concepts, e.g. energy recovery, energy efficiency, and possibly particle (e.g. positron) recycling** (**CERN, GSI, CNRS, PSI, + JGU – Florian Hug**)

Summary of WP5.2 (PAF) activities so far

- *iFAST* ***Extreme Storage Rings*** *workshop, zoom, 31 Jan- 8 Feb 2022* *https://indico.cern.ch/event/1096767/ ; summary report: https://doi.org/10.5281/zenodo.6481111*

  150 expert participants from around the world, including CERN (13), GSI (23), PSI (5) , CNRS (4)., JGU/HI Mainz (1), DESY (8), etc.

  Highlights: first demonstration of optical stochastic cooling, ultimate light sources, coherent electron cooling, precision experiments, quantum computing based on storage rings, Gamma Factory …

- *ARIES & iFAST SMART joint* ***Brainstorming & Strategy*** *ws, Valencia, 29 Mar – 1 Apr 2022 https://indico.cern.ch/event/1133593/ ; summary report: https://doi.org/10.5281/zenodo.7071937 ;* 14 participants: CERN (6), GSI (1), PSI (1) , CNRS (1)., DESY (2), LANL (1) , FNAL (2), LPNHE (1)

  Themes: (1) present and future AI accelerator applications, and (2) beam requirements and accelerators for the dark sector. Highlights: LHC-based Gamma Factory driving subcritical nuclear reactor, classification and requirements for dark sector searches, roadmap for machine learning in the field of accelerators

- *Co-sponsored FCC-ee Injector Studies Mini-Workshop, IJCLab, 24-25 Nov 2022 , https://indico.ijclab.in2p3.fr/event/8920/*

- *Topical iFAST workshop on* ***Accelerators for the Dark Sector****, CERN, 31 Oct 2022* https://indico.cern.ch/event/1217033/ ; summary: https://doi.org/10.5281/zenodo.7299802 ; 7 participants: CERN (4), PSI (2), CNRS (1)

  Highlights: dielectric laser acceleration (DLA) promising candidate for indirect searches of dark sector; parameter sets for baseline and advanced DLA-based schemes, incl. dielectric laser deflectors and segmented detectors

- *Co-sponsored FCC-ee Pre-Injector meeting, INFN-LNF, 20-21 April 2023, https://agenda.infn.it/event/34369/*

snapshot - **BSW22 Valencia**

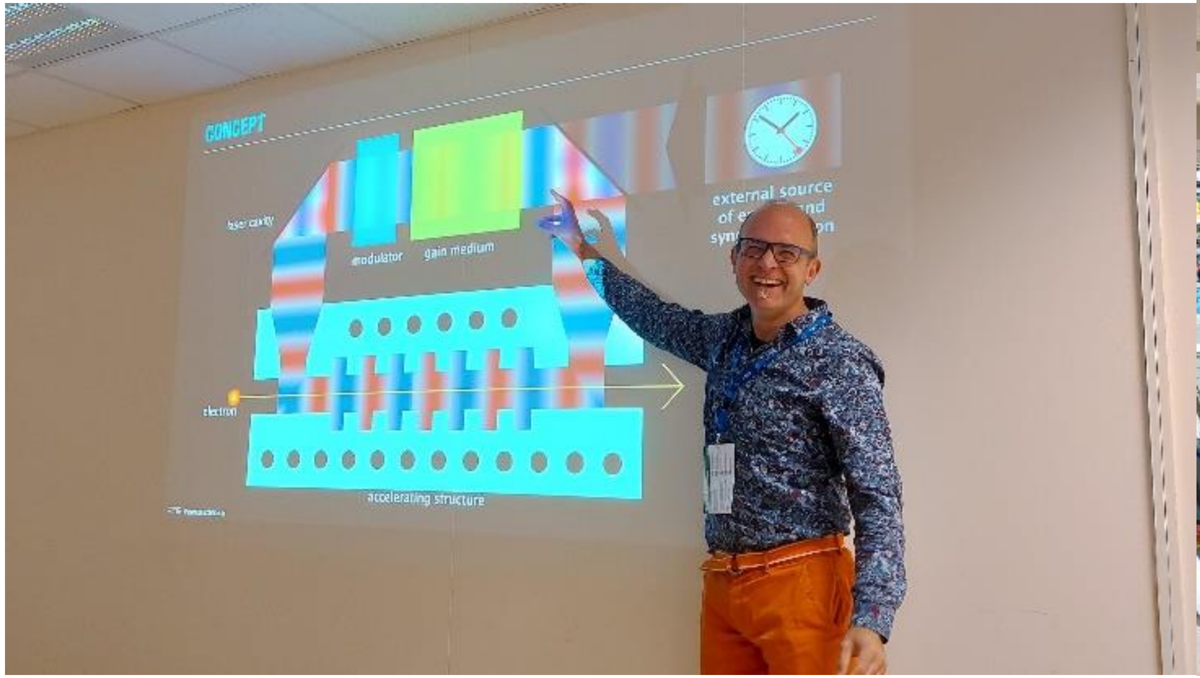
ARIES WP6 APEC & iFAST WP5.2 SMART PAF brainstorming & strategy ***in-person non-virtual*** meeting

29 March – 1 April 2022

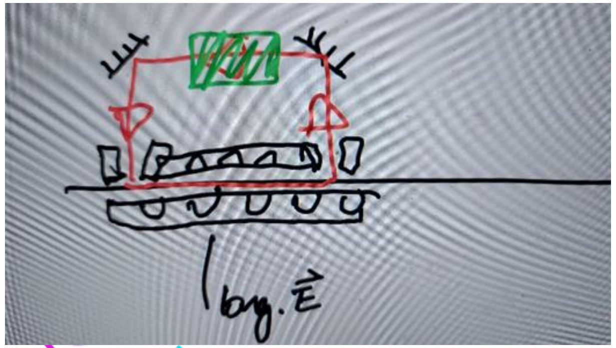
organizers: Angeles Faus Golfe (IJCLab), Giuliano Franchetti (GSI), Frank Zimmermann (CERN)

main themes: **Dark Sector Accelerators** & **Machine Learning**

Snapshot - *Topical iFAST workshop on* ***Accelerators for the Dark Sector****, CERN, 31 Oct 2022*



Two photographs from the topical dark-sector acceleration iFAST meeting, held at CERN, on 31 October 2022.



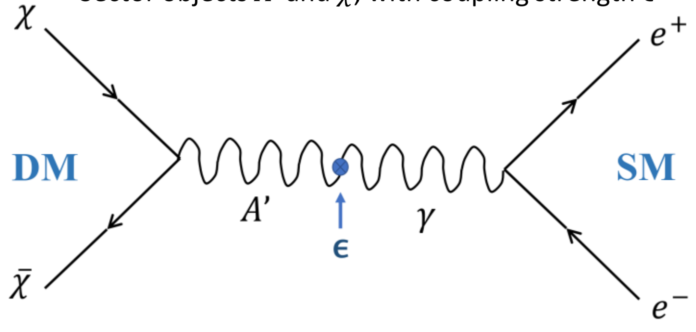
Hand-drawn sketch of DLA structure as part of a laser oscillator. The beam moves from left to right through the structures, while the laser pulse circulates at a rate of 100 GHz (path length ~3 mm) [drawn by R. Ischebeck on a green field, while riding a bike to PSI].

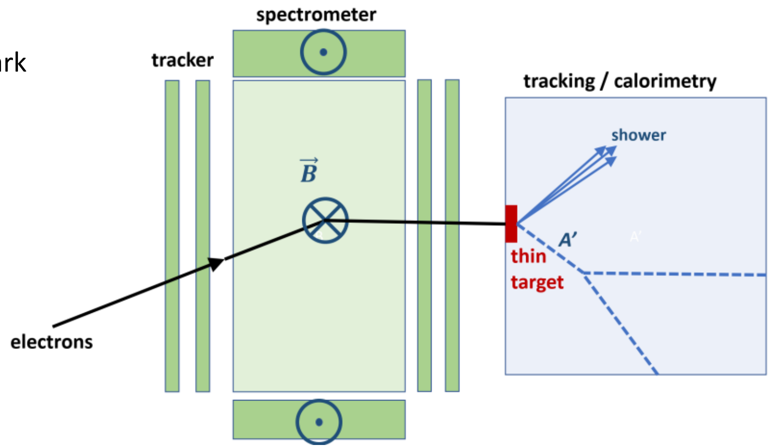
iFAST highlight talk by Raziyeh Dadashi !

DLA for dark sector searches – the punchline

iFAST highlight talk by Raziyeh Dadashi !
iFAST IPAC’23 papers

Feynman diagram illustrating coupling of Standard Model particles and photons to the corresponding Dark Sector objects A' and χ, with coupling strength ϵ

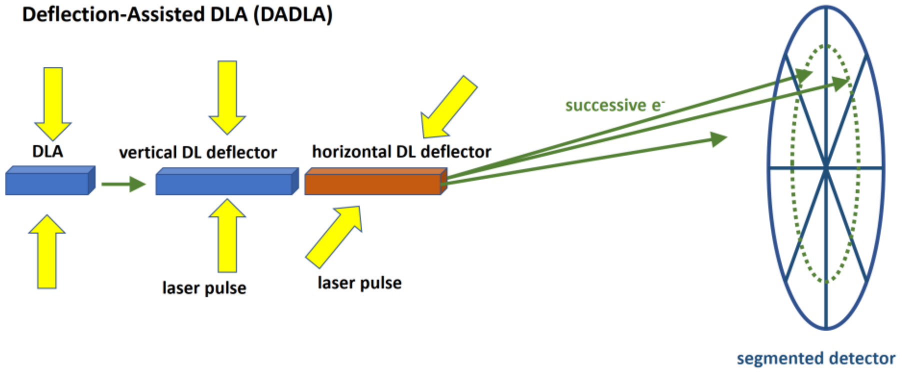




Concept of indirect DM search by missing momentum with spectrometer and trackers upstream and calorimeter downstream of a thin target. A' indicates a particle carrying missing energy

Table 1: Three parameter sets for a linear collider with advanced high gradient acceleration [2, 6, 7].

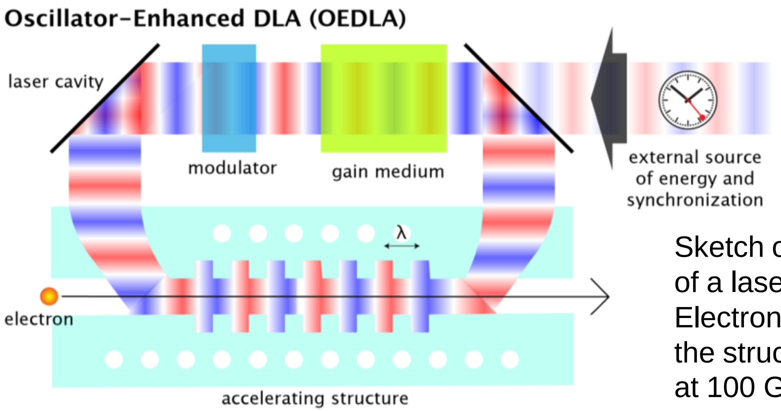
Parameter [unit]	PWFA	LWA	DLA
Bunch charge [nC]	1.6	0.64	5×10^{-6}
No. bunches / train	1	1	159
Train rep. rate [kHz]	15	15	20000
Norm. emit. ($\gamma\varepsilon$) [nm]	592	100	0.1
Beam power (5 GeV) [kW]	120	48	76
Relative energy spread [%]		≤ 0.35	



DLA deflectors are sending each electron in a train of ~160 onto a separate segment of the detector, thereby overcoming the time resolution limit and allowing bunch spacing of less than 10 ps within a train.

Table 2: Three options for DLA based dark sector searches.

DLA scheme	MDLA	DADLA	OEDLA
e^- energy [GeV]	10	10	10
Gradient [GV/m]	1	1	1
Act. length [m]	10	10	10
Rep. rate [GHz]	0.06	0.06	100
Pulse length [ps]	0.1	1	0.1
Single e's / pulse	1	160	1
Av. current [pA]	1	150	
Time sep. [ns]	17	17 btw. pulses (7 fs in pulse)	0.01
Special features	—	DL defl., segm. det.	DLA in laser osc.
e^-/yr (2×10^7 s)	6×10^{14}	$\sim 10^{17}$	$\sim 10^{18}$
Energy/yr [GWh]	1	10	~ 2



Sketch of a DLA structure as part of a laser oscillator (OEDLA). Electrons pass rightwards through the structure; laser pulse circulates at 100 GHz (path ~3 mm)

Recent Milestone

Task 5.2 Milestone MS17:

Beam requirements for dark-sector searches

due in M18, 31/10/2022

Report *delivered on time & approved*

https://zenodo.org/record/7299802#.ZD61wvxBxPY

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Innovation Fostering in Accelerator Science and Technology

Horizon 2020 Research Infrastructures GA n° 101004730

MILESTONE REPORT

Beam requirements for dark-sector searches

MILESTONE: MS17

Document identifier:	IFAST-MS17
Due date of deliverable:	End of Month 18 (October 2022)
Report release date:	31/10/2022
Work package:	WP5: SMART, Task 2: PAF
Lead beneficiary:	CERN
Document status:	Draft

ABSTRACT

Particle accelerators can contribute to dark sector searches over a large energy range. Present and proposed lepton and hadron colliders can search for sterile neutrinos and feebly coupled particles, including forward detectors at the LHC and an LHC-based Gamma Factory. Also, a muon storage ring could play a role for dark neutrino searches. A different approach to the dark sector is beam dump experiments, using either proton, like SHIP, or electron beams, such as BDX and LDMX. Both indirect and direct detection is pursued. In particular, for indirect beam dump experiments with electron beams, advanced accelerator concepts could offer an attractive path forward, such as plasma acceleration based on the AWAKE scheme. In this paper we identify and discuss dielectric laser acceleration (DLA) as a promising candidate for delivering interesting rates of individual electrons in the 5-100 GeV energy range or beyond. We present a baseline parameter set for a DLA-based dark sector searcher. Enhancements with dielectric laser deflectors and segmented detector or by making the dielectric structure be part of the laser oscillator might offer a performance well exceeding the "Extended LDMX" proposal based on LCLS-II.

WP5.2 parallel coordination meeting, Trieste 19 April 2023

Upcoming Milestone

Task 5.2 Milestone MS18:

Present and future AI accelerator applications

due in M24, 30/04/2023

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Innovation Fostering in Accelerator Science and Technology

Horizon 2020 Research Infrastructures GA n° 101004730

MILESTONE REPORT

Present and future AI accelerator applications

MILESTONE: MS18

Document identifier:	IFAST-MS18
Due date of deliverable:	End of Month 24 (30 April 2023)
Report release date:	30/04/2023
Work package:	WP5: SMART, Task 2: PAF
Lead beneficiary:	CERN
Document status:	Draft

ABSTRACT

Artificial intelligence and machine learning are rapidly gaining importance in a large number of particle-accelerator domains, such as safe accelerator optimisation, automated beam operation, virtual diagnostics, fault and anomaly detection, accelerator design, and data analysis. The new tools may not only lead to better performance, but also lower the cost of future and existing machines. Machine Learning already widely contributes to the exploitation of operating accelerator facilities. In this article, we illustrate dozens of successful developments at CERN, DESY, FNAL, LANL, PSI, and SLAC, indicate directions for further developments, list open questions, and issue R&D recommendations. Amongst others we advise that ML should become a standard topic in accelerator education. Further work is needed on time-varying systems. A question to explore is special applications for quantum computing in the field of accelerators. Most importantly, we should seek collaborations with ML experts from other sectors, and we recommend building a testbed for self-controlling complex accelerators.

Upcoming co-sponsored event

Channeling 2023

The 9th International Conference

Charged & Neutral Particles

Channeling Phenomena

4-9 June 2023
Riccione (Rimini), Italy

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

CERN

http://www.lnf.infn.it/conference/channeling2020

Topics

- coherent scattering of relativistic charged particles in strong fields;
- crystal channeling, volume capture and volume reflection of hadron and lepton beams;
- energetic ion interactions processes
  - backscattering and channeling of low energy ions,
  - high energy ion channeling;
- electromagnetic radiation by relativistic charged particles in periodic structures
  - coherent bremsstrahlung,
  - channeling radiation,
  - transition radiation,
  - diffraction radiation,
  - parametric x-ray radiation,
  - Landau-Pomeranchuk-Migdal effect,
  - free electron laser,
  - Compton scattering;
- channeling of radiations in capillary systems
  - micro- and nano-channeling,
  - micro-channel plates,
  - nanotubes,
  - nano-porous;
- novel techniques for beams handling and acceleratio
  - plasma wake-fields,
  - cross-laser fields,
  - crystal assisted collimation,
  - plasma-ion channels,
  - capillary channeling;
- advanced x-ray & neutron optics
  - capillary/polycapillary optics,
  - compound refractive optics,
  - micro- and nano-focusing,
  - waveguides;
- applications based on channeling phenomena
  - beams shaping,
  - positron sources,
  - powerful radiation sources,
  - diagnostic tools,
  - novel x-ray table-top instruments,
  - channeling for advanced electronic materials stud

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Channeling 2023

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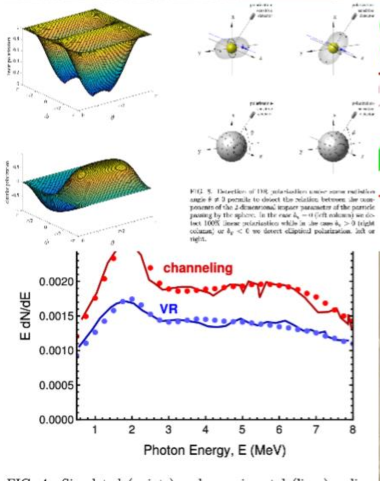

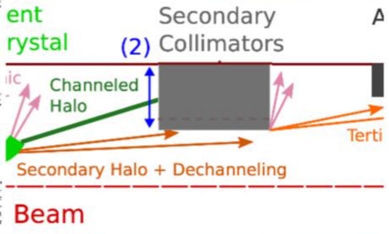

Channeling 2020/21@22 has been portponed to June 4-9, 2023 becoming Channeling 2023

The 9th International Conference
Channeling 2023
Charged & Neutral Particles Channeling Phenomena
Riccione (RN) - Italy - June 4 - 9, 2023
Hotel CORALLO

organized by
Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Frascati (INFN LNF)
European Organization for Nuclear Research (CERN)

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SIF – Italian Physical Society
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X Channel
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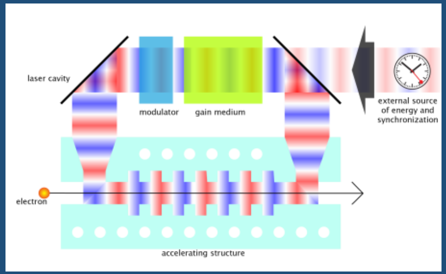
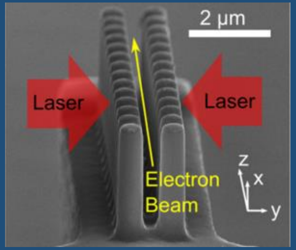
planned WP5.2 events

GR^{2}M - GHz Rate & Rapid Muon Acceleration for Particle Physics

Joint mini-workshop of iFAST WPs 5 and 6
Tentative location: Bern, Switzerland
Tentative time: **Nov or Dec 2023**

Programme committee, unfolding
Ralph Assmann, DESY
Giuliano Franchetti, GSI
Rasmus Ischebeck, PSI (Chair)
Frank Zimmermann , CERN (co-Chair)





"IPS" – Intense Positron Sources

Tentative location: Paris
Tentative time: autumn 2023 or spring 24

RFA24 – Roadmap for Future Accelerators

Tentative location: Germany, larger Frankfurt area
Tentative time: Sept 2024

Relevance of WP5.2 (PAF) objectives & impact

- *Machine learning, dark sector searches, and sustainable accelerators (ERLs, GF, …) are attracting ever larger interest in the community; SMART-PAF is developing roadmaps and guidance*
- *Efficient e^+ production is important for future e^+e^- Higgs factory of any flavor*
- *We further explore intriguing far-future possibilities, such as quantum computing, gravitational wave detection, and energy production using storage rings*

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WP5.2 PAF Publications

Frank Zimmermann, ***Accelerator Technology and Beam Physics of Future Colliders***, **Front. Phys.,** 23 May 2022, Sec. Radiation Detectors and Imaging, Volume 10 - 2022 | https://doi.org/10.3389/fphy.2022.888395

F. Zimmermann, Y. Papaphilippou, A. Poyet, ***Impact of Longitudinal Gradient Dipoles on Storage Ring Performance***, **Proc. IPAC'22**, p. 30

G. Franchetti, F. Zimmermann, ***Trapping of Neutral Molecules by the Electromagnetic Beam Field***, **Proc. IPAC'22**, p. 1649

F. Zimmermann, A. Latina, M. Antonelli, M. Boscolo, A.P. Blondel, J.P. Farmer, ***Muon Collider Based on Gamma Factory, FCC-ee and Plasma Target***, **Proc. IPAC'22**, p. 1691

James Beacham and Frank Zimmermann, ***A very high energy hadron collider on the Moon***, **New J. Phys**. 24 023029, DOI 10.1088/1367-2630/ac4921

I. Chaikovska et al., ***Positron sources: from conventional to advanced accelerator concepts-based colliders***, JINST 17 P05015, 2022

L. Bandiera et al., ***Crystal-based pair production for a lepton collider positron source***, EPJ C vol. 82, 699 (2022)

F. Zimmermann, ***Beam Physics Frontier Problems***, submitted to Proc. eeFACT'22 ICFA workshop

G. Franchetti & F. Zimmermann, ***Impact of the Neutral Molecule Trapping on Beam Lifetime and Beam Profile***, IPAC'23

F. Zimmermann et al., ***Dark Sector Searches Based on Dielectric Laser Acceleration***, IPAC'23

in addition to the various workshop summary & milestone reports on zenodo

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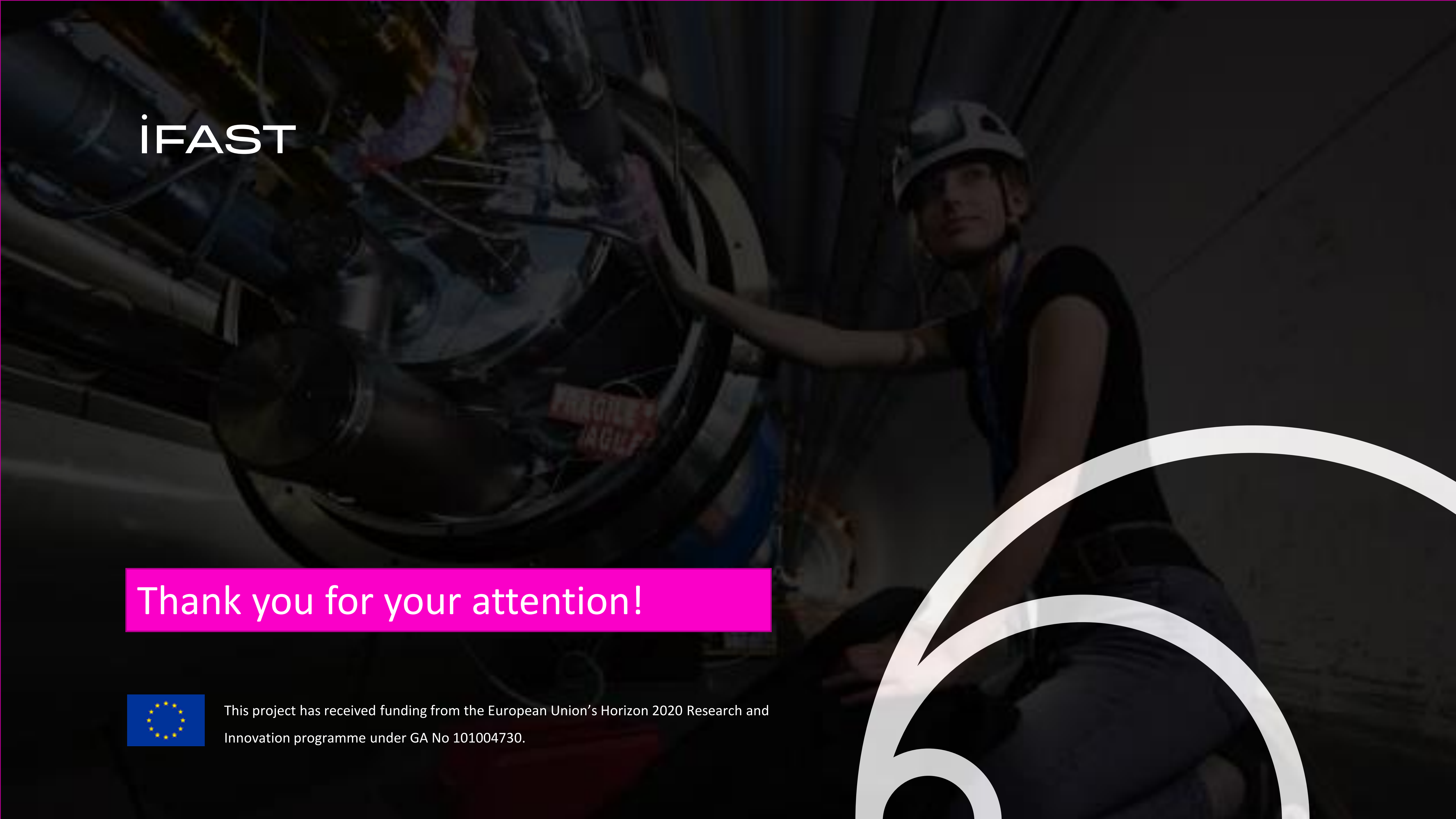

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Thank you for your attention!

This project has received funding from the European Union’s Horizon 2020 Research and Innovation programme under GA No 101004730.

spare slides

WP5 milestones

MS15	International workshop on muon source design	5.1	M18
MS17	**Beam requirements for dark-sector searches**	**5.2**	**M18**
MS18	**Present and future AI accelerator applications**	**5.2**	**M24**
MS20	Engineering design of improved power supply current measurement and RF-amplifier layout	5.3	M24
MS16	International workshop to define R&D plans	5.1	M36
MS19	**Ultimate hadron-beam brightness**	**5.2**	**M48**

WP5 deliverables

D5.1: International collaboration plans towards a multi-TeV muon collider Report on established collaboration and results disseminated by the action [MUST]	M46
D5.2: Roadmap for future accelerators **Strategy for intense positron sources; R&D plan towards ultimate beams; State of the art and possible directions for crystalline beams; Strategy and requirements for EDM ring or other precision experiments; Roadmap for accelerator AI; State of the art and future roadmap for green accelerators [PAF]**	**M42**
D5.3: Ripple mitigation for slow extraction beam quality improvement Simulation results for improvements including their experimental verifications, and design considerations of the accelerator control with related hardware. [REX]	M46

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