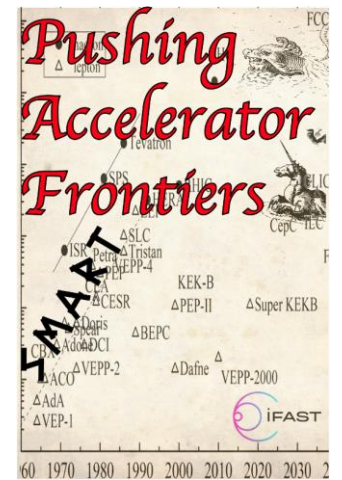




Frank Zimmermann, CERN

Peter Forck, GSI; [Giuliano Franchetti, GSI](#)

I.FAST Period 1 Review, 07.02.2023



WP5.2 & 5.3 structure and objectives

Task 5.2 Pushing Accelerator Frontiers (PAF)	Task 5.3 Improvement of Resonant slow EXtraction spill quality (REX)
Coordinators: Frank Zimmermann (CERN), Giuliano Franchetti (GSI)	Coordinator: Peter Forck (GSI)
<i>CERN, GSI, CNRS, PSI + JGU Mainz</i>	<i>GSI, Bergoz Inst., Barthel, CERN, HIT Heidelberg</i>
Significantly improve the performance of lepton and hadron accelerators	Mitigate intensity fluctuations of slowly extracted beam from synchrotrons by means of detailed parameter simulations, related experimental verifications, and active beam control
Identify novel accelerator opportunities and possible implementations	Produce a prototype of improved hardware for power supply control to achieve a current stability in the range of $\Delta I / I < 10^{-6}$.
Define a roadmap for long-term accelerator R&D	Design and produce a high-performance RF-amplifier with versatile control for knock-out extraction.

Summary of WP5.2 (PAF) activities in P1

- ***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

- ***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)

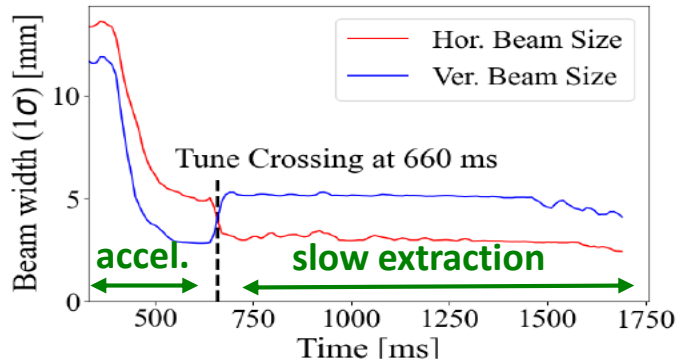
Highlights: dielectric laser acceleration (DLA) promising candidate for indirect searches of dark sector; parameter sets for baseline and advanced DLA-based schemes, incl. dielectric laser deflectors and segmented detectors

Summary of WP5.3 (REX) activities in P1: Beam Physics

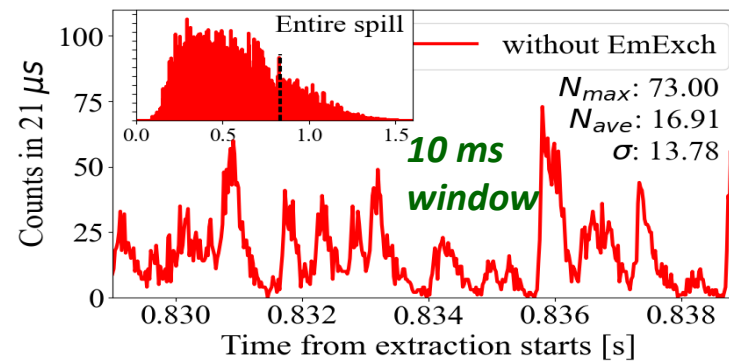
- **Detailed beam experiments, e.g. commonly at GSI and HIT**

One Example: Hori.-vert. emittance exchange by coupling resonance $Q_x = Q_y + 1$ crossing

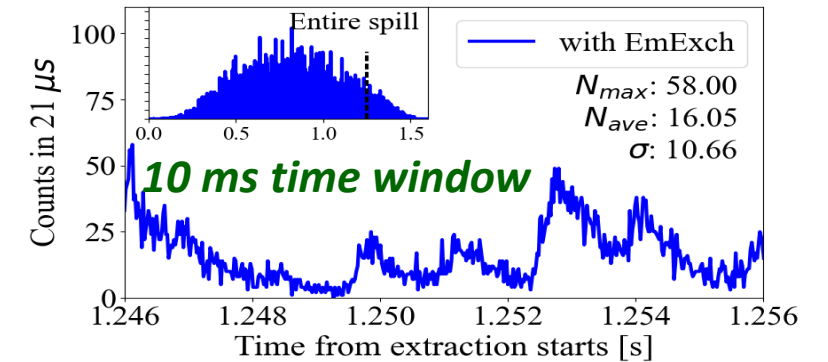
Beam profile within synchrotron:



Beam fluctuations without improvement:



Beam fluctuations with improvement:



- **Detailed beam experiments at HIT synchrotron (intensive HIT-GSI collaboration)**

- BTF measurement of stored beam close to 3rd order resonance \Rightarrow separatrix shape
- Beam fluctuations for various knock-out excitation spectral shapes \Rightarrow significant improvement

- **Detailed beam dynamics simulations for beams**

- Extensive simulation for extraction to compare to experiment, mainly with MAD-X
- Introduction of **Xsuite** as novel Python-based development at CERN to combine various methods

\Rightarrow **extensive collaboration between CERN, GSI, MedAustron, SEEIIST (in particular between PhD students)**

Summary of WP5.3 (REX) activities in P1: Technology

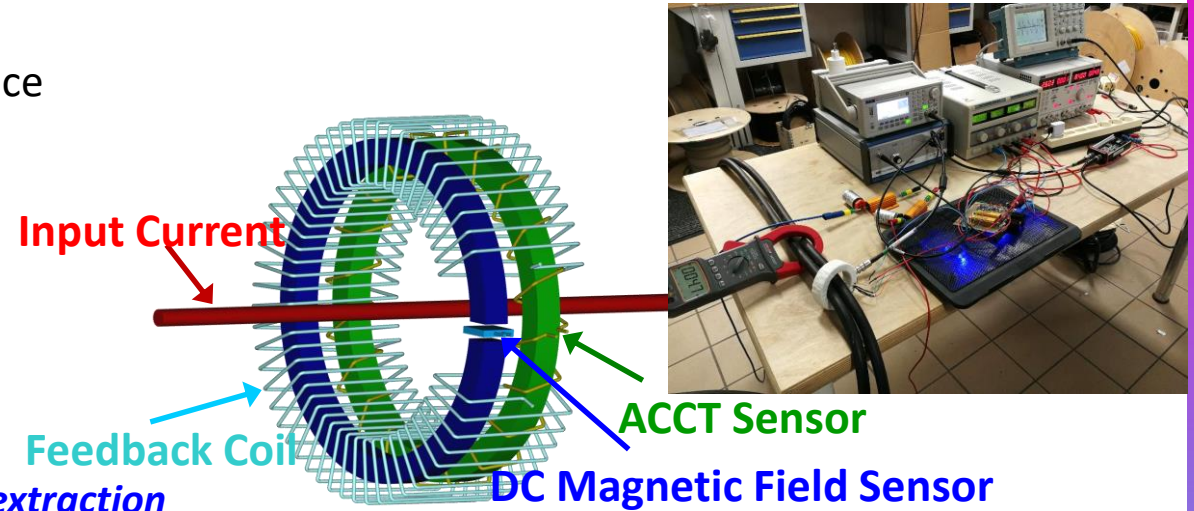
- **Prototype for ac-power supply stabilization**

Topic: Broadband, high dynamic range current measurement device

Novelty: Measurement for additional power supplier control,
reached sensitivity: $I_{AC} / I_{DC} < 10^{-5}$

Status: First layout as novel device.

Developed by company Bergoz in collaboration with GSI & CERN



- **High-performance RF-amplifier with versatile control for knock-out extraction**

Control: Commercial 'Software-defined radio' operating via software

Amplifier: Modified system from Barthel HF-Technik

Status: Functionality proven at HIT and GSI.

Developed by company Barthel HF-Technik in collaboration with HIT & GSI

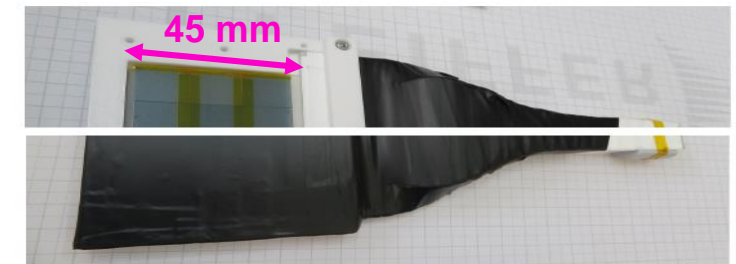


USRP N210 based signal generator

- **Detector for single particle counting**

Novelty: ZnO:In scintillator → fast counting (≈ 5 ns), size 45×45 mm²,
radiation hardness ≈ 100 times of plastic scintillator

Beam tests and material characterization performed by GSI



Scintillator prototype



Deliverables and Milestones P1

Task 5.2

Milestone MS17:

Beam requirements for dark-sector searches

due in M18, 31/10/2022

Report *delivered on time & approved*

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*

Relevance of WP5.3 (REX) objectives & impact

- **Modelling of slow extraction significantly improved:**
 - Performed by traditional tools like MAD-X and modern frame Xsuite
 - Intensive discussion on beam physics close to a 3rd-order resonance
 - Intensive exchange of knowledge between participants
 - **Common experiments at various facilities and verification of improvements:**
 - Significant mitigations of beam current fluctuations achieved and interpreted
 - Good collaboration & cooperation between participants
 - **General technical developments:**
 - Extreme high dynamic range ac-current measurement
 - Versatile, user-friendly rf-signal generation with GNU-Radio
 - Detector development for high count rate and related data management
- ⇒ Significant mitigations concerning beam current fluctuation achieved
- ⇒ General progress concerning technologies for measurements and accelerator control
i.e. better beams for experiments and cancer treatment patients
- ⇒ Project in good swing thanks to motivated participants, further key results expected ...

iFAST

Thank you for your attention!



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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

F. Zimmermann, *Beam Physics Frontier Problems*, submitted to Proc. eeFACT'22 ICFA workshop in addition to the three workshop summary & milestone reports on zenodo

WP5.3 REX Publications

Publication with IFAST-REX acknowledgement:

- J. Yang, P. Forck, T. Giacomini, P. J. Niedermayer, R. Singh, and S. Sorge, *Improvement of Spill Quality for Slowly Extracted Ions at GSI-SIS18 via Transverse Emittance Exchange*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-WEPOTK021
- J. Yang, P. Boutachkov, P. Forck, T. Milosic, R. Singh, S. Sorge, *Beam Characterization of Slow Extraction Measurement at GSI-SIS18 for Transverse Emittance Exchange Experiments*, Proc. IPIC'22, Krakow, Poland, doi:10.18429/JACoW-IBIC2022-TUP36
- P.J. Niedermayer, R. Singh, *Novel Beam Excitation System Based on Software-Defined Radio*, Proc. IPIC'22, Krakow, Poland, Sept. 2022, Poster MOP36, doi:10.18429/JACoW-IBIC2022-MOP36

Further related publication from IFAST-REX consortium:

- E.C. Cortes Gracia et al., *Optimization of the spill quality for the hadron therapy at the Heidelberg Ion-Beam Therapy Centre*, Nucl. Instrum. Meth. A Volume 1040, 1 October 2022, 16713 <https://doi.org/10.1016/j.nima.2022.167137>
- P. J. Niedermayer and R. Singh, *Transverse Excitation and Applications for Beam Control*, in Proc. IPAC'22, Bangkok, Thailand, Jun. 2022, pp. 251-253. doi:10.18429/JACoW-IPAC2022-MOPOPT011
- P. A. Arrutia Sota, P. Burrows, H. Damerau, M. A. Fraser, M. Vadai, and F. M. Velotti, *Implementation of RF Channeling at the CERN PS for Spill Quality Improvements*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-WEPOTK028
- A. Arrutia Sota et al., *Implementation of a Tune Sweep Slow Extraction with Constant Optics at MedAustron*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-WEPOST015
- E. Feldmeier et al., *Upgrade of the Slow Extraction System of the Heidelberg Ion-Beam Therapy Centre's Synchrotron*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-THPOST029
- E. C. Cortés García, E. Feldmeier, and Th. Haberer, *Horizontal Beam Response at Extraction Conditions at the Heidelberg Ion-Beam Therapy Centre*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-WEPOTK022
- R. L. Taylor, E. Benedetto, J. Pasternak, and M. Sapinski, *Slow Extraction Modelling for NIMMS Hadron Therapy Synchrotrons*, Proc. IPAC'22, Bangkok, Thailand, doi:10.18429/JACoW-IPAC2022-THPOMS019