what is iFAST WP5?

WP5: Strategies and Milestones for Accelerator Research and Technologies (SMART)

Peter Forck (GSI), Giuliano Franchetti (GSI), Nadia Pastrone (INFN), Frank Zimmermann (CERN)


iFAST 1st Annual Meeting, 5 May 2022


Participating Institutes:
INFN, CERN, CEA, CNRS, KIT, PSI, United Kingdom Research and Innovation, GSI, Bergoz Instrumentation, Barthel HF-Technik GmbH, HIT Heidelberg + JGU Mainz

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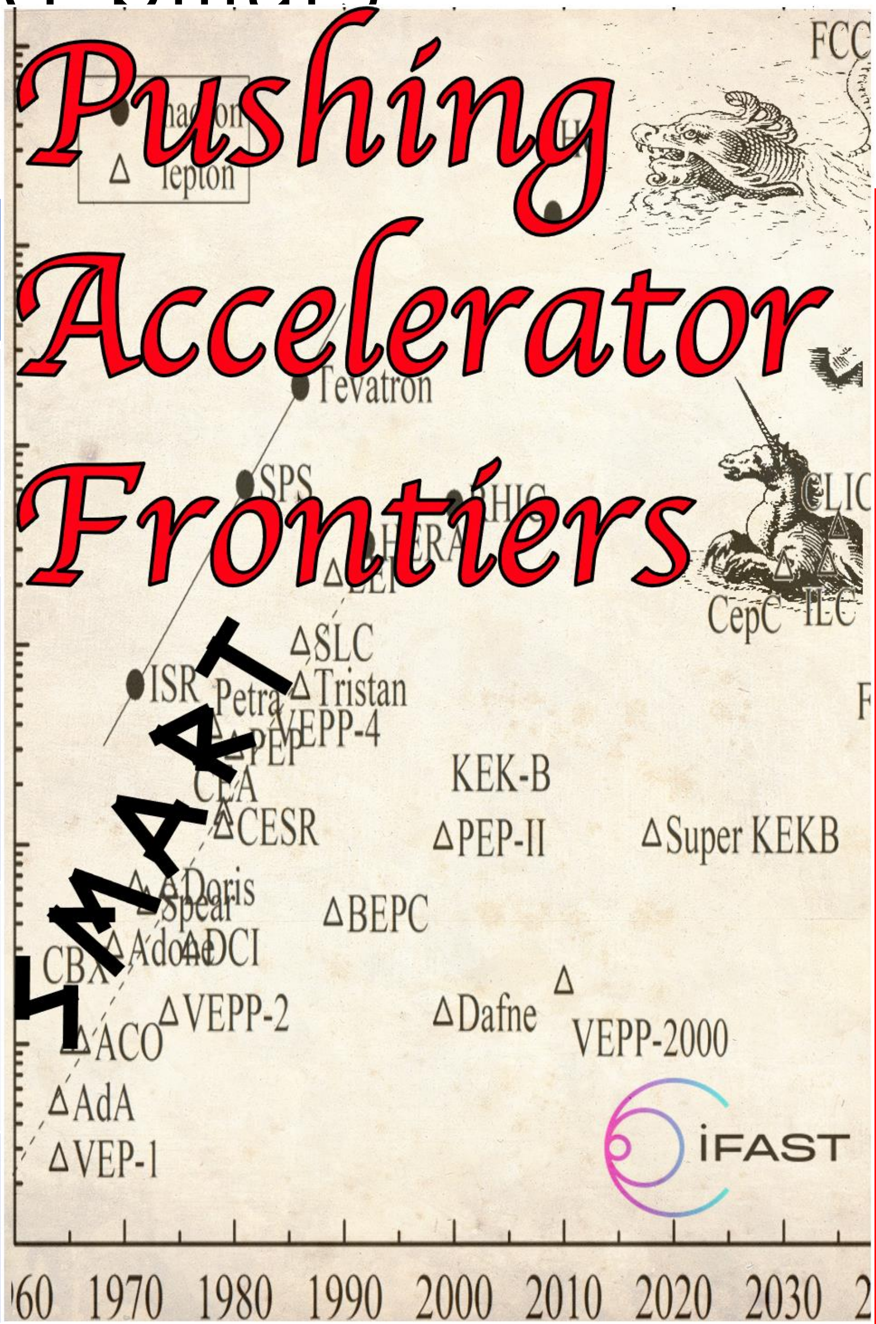
the three SMART pillars

Task 5.1 MUon colliders STrategy network (MUST)
Coord.: Nadia Pastrone (INFN)
<u>INFN</u>, CERN, CEA, CNRS, KIT, PSI, UKRI
Support the effort to design a muon collider and to project and plan the required R&D.
Consolidate the community devoted to developing an international future facility.
Prepare the platform to disseminate the information



Task 5.3 Improvement of Resonant slow EXtraction spill quality (REX)
Coord.: Peter Forck (GSI)
<u>GSI</u>, BI, BT, CERN, HIT
Mitigate intensity fluctuations of slowly extracted beam from synchrotrons by means of detailed parameter simulations, related experimental verifications, and active beam control
Produce a prototype of improved hardware for power supply control to achieve a current stability in the range of $\Delta I / I < 10^{-6}$.
Design and produce a high-performance RF-amplifier with versatile control for knock-out extraction.

Task 5.2 Pushing Accelerator Frontiers (PAF)

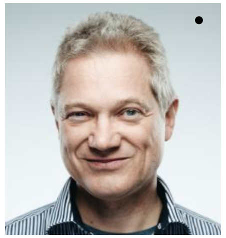
- **Main tools:** **topical workshops and dedicated prospective studies**

- **Overriding goal:** survey **frontiers of classical accelerators and develop long-term strategies** for boosting the performance of **future facilities** and for **overcoming limitations**

- **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,..**
  - review the ultimate limits on **high-gradient acceleration, high-field bending, beam size, beam density, and luminosity**



- F. Zimmermann, R. Assmann, M. Bai, G. Franchetti, *Review of Accelerator Limitations and Routes to Ultimate Beams*, IPAC'21

- IPAC'21 paper

Task 5.2 Pushing Accelerator Frontiers (PAF) – cont'd

- **Thrust 3: artificial intelligence for accelerators,** exploring applications of **machine learning, deep learning, advanced optimization algorithms and neural networks**, for accelerator control and design (**PSI – Rasmus Ischebeck**)

- **Thrust 4: accelerators for "dark sector"& precision 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

Task 5.2 Pushing Accelerator Frontiers (PAF) – cont'd

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**)

WP5 - **Task 5.2 PAF synergies:**
with Task 5.1 MUST: positron sources, ultimate limits, and particle recycling ..
with the Task 5.3 REX: dark sector fixed-target experiments and machine learning …

→ PAF will develop a coherent landscape for future accelerators and issue targeted R&D recommendations

two PAF workshops so far

- ***Extreme Storage Rings Workshop (ESRW22)*** – virtual – 31 January to 8 February 2022

  https://indico.cern.ch/event/1096767/

115 participants (17 participants or 14% women)

ESRW22 summary report published in ICFA Beam Dynamics Newsletter #83 (JINST journal) and submitted to Accelerating News

- ***PAF brainstorming & strategy workshop (BWS22)*** – in person – 30 March to 1 April 2022

  https://indico.cern.ch/event/1133593/

  - topics:

    (1) present and future AI accelerator applications

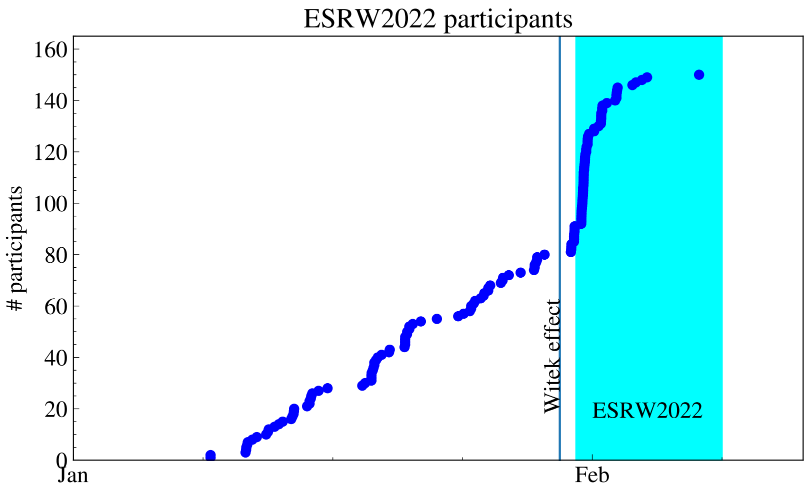
    (2) beam requirements and accelerators for the dark sector

14 participants (3 participants or 21% women)

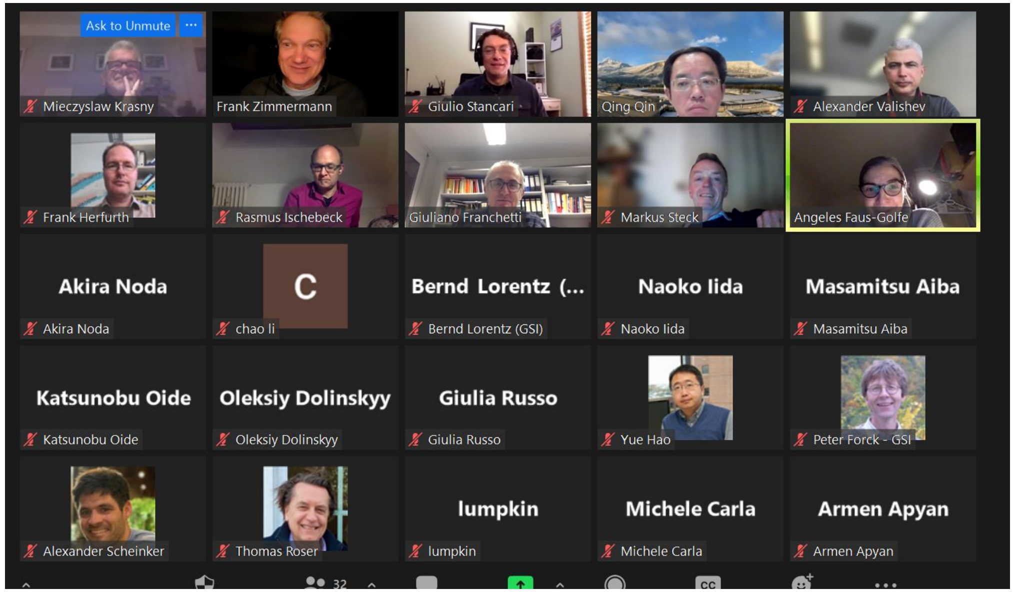
Extreme Storage Rings Workshop (ESRW22)

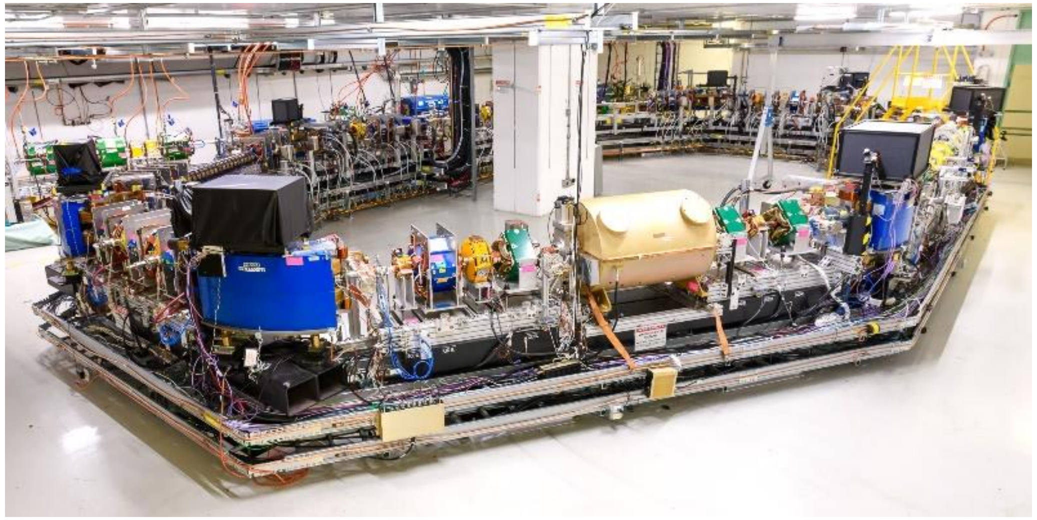
- Cross-boundary subjects with added value from collaboration and sharing of resources.
- Collaborative schemes involving laboratories, university and industry.
- Priority to longer-term high-risk high-gain R&D.

Maurizio Vretenar



Session 1 : State of the art of storage rings



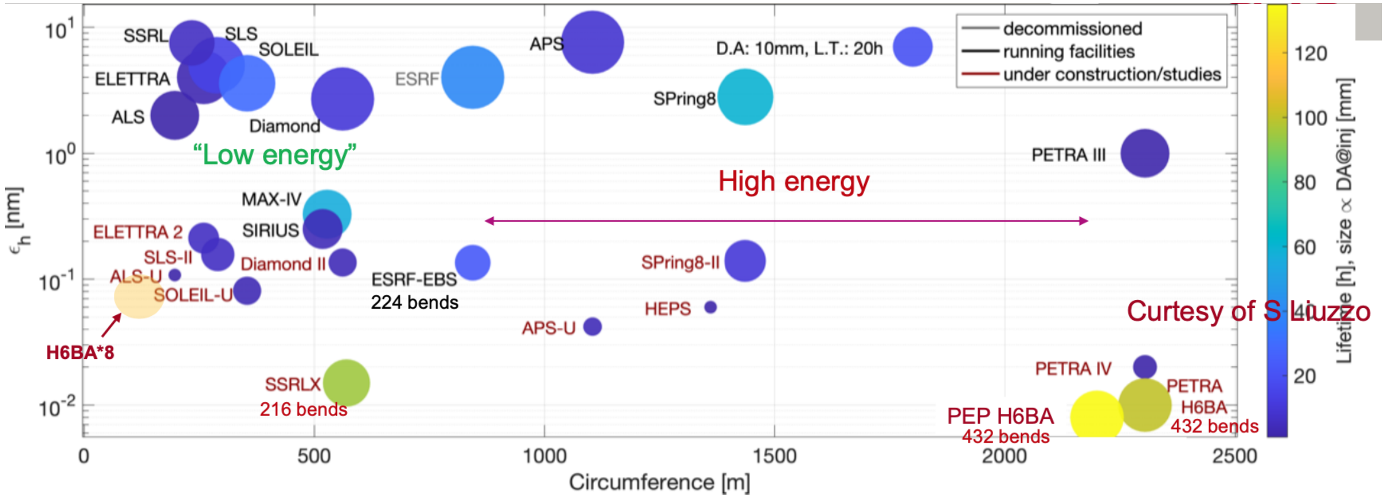


First experimental demonstration of optical stochastic cooling was reported from the IOTA facility at FNAL.

Giulio Stancari, FNAL

Session 2 : Limits and prospects for future lepton and hadron storage rings

Pantaleo Raimondi, SLAC

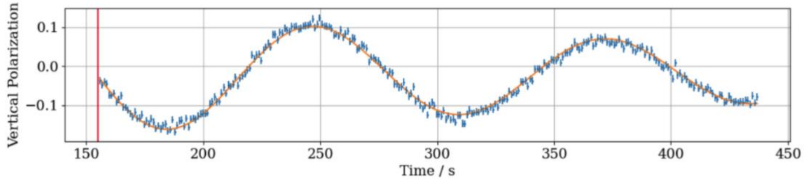


Emittance (vertical axis), beam lifetime (colour), and dynamic aperture (size of circle) for present and future light source – four ultimate light source designs were proposed (H6BA*8, SSRLX, PEP H6BA, and PETRA IV)

Session 3: Precision experiments w storage rings

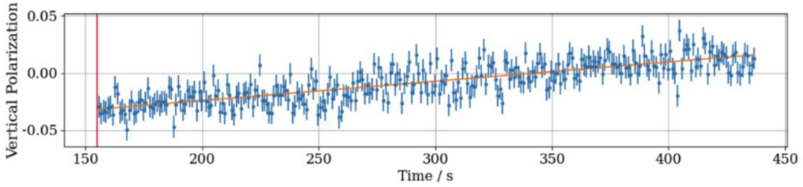
Observation of $p_y(t)$ with two stored bunches: **Signal and pilot bunch**

- Signal bunch



- Pilot bunch

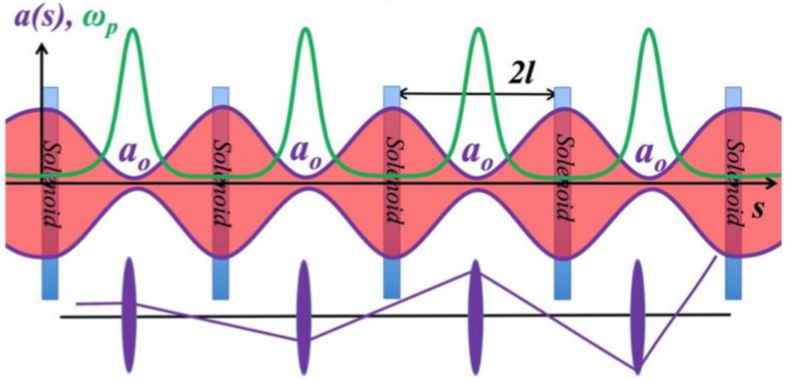
Frank Rathmann, FZJ



Bunch-selective spin manipulation and decoherence at COSY

Session 4: Beam stabilization and diagnostics

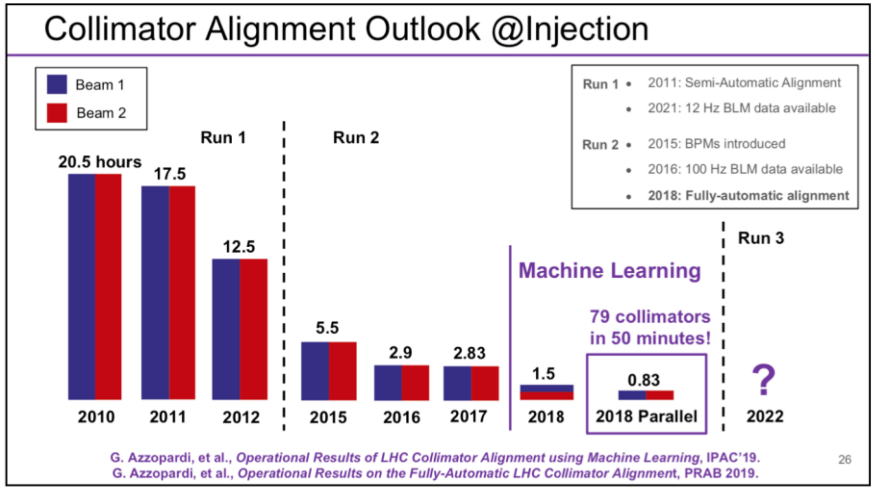
$$\tilde{n}'' + \omega_p^2(s)\tilde{n} = 0$$



Irina Petrushina, SBU

Schematic of plasma cascade instability

Session 5: Applications of machine learning

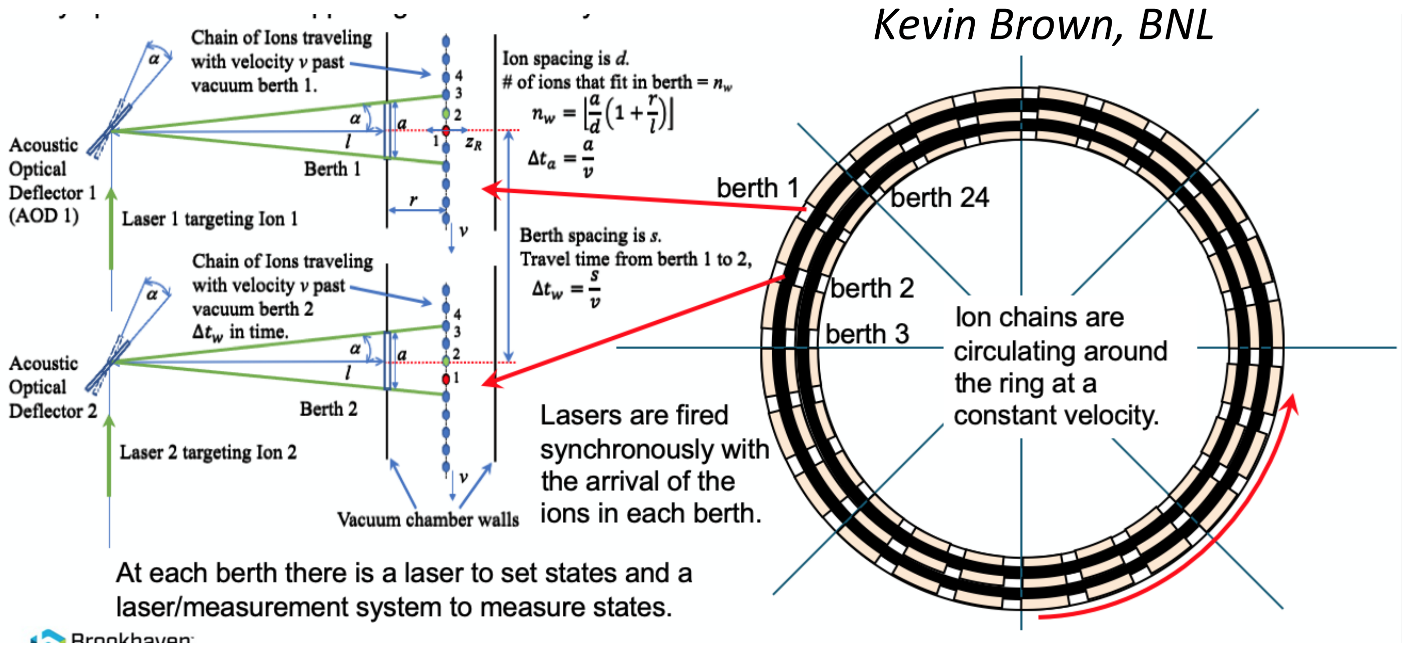


Verena Kain, CERN

Improved LHC collimator setup time thanks to machine learning

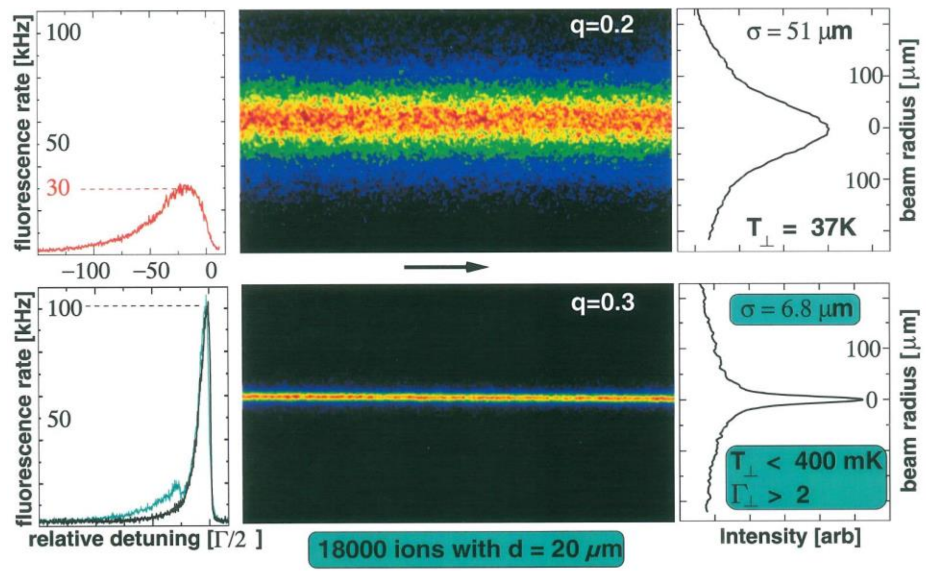
Session 6: Crystalline beams and quantum computers based on stored beams

Kevin Brown, BNL



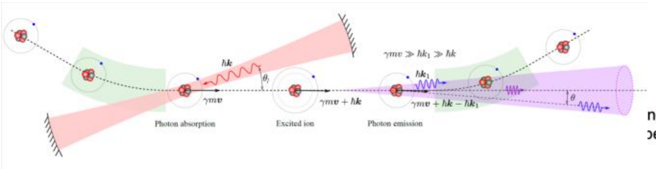
Concept of storage-ring based quantum computer

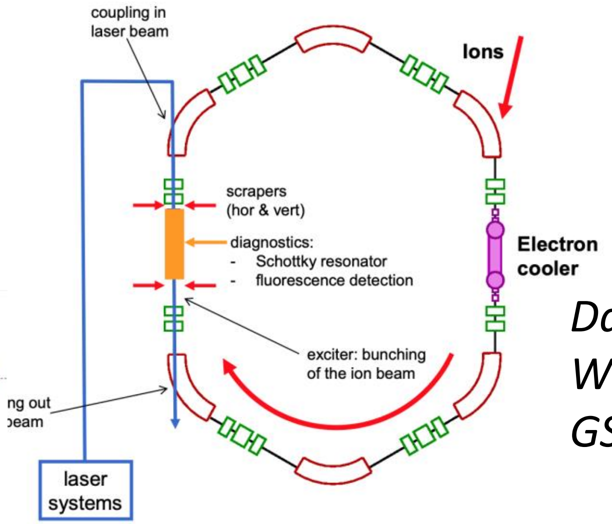
Tobias Schaetz, U. Freiburg (& LMU)



Crystalline beam at PALLAS

Session 7: Advanced cooling and Gamma Factory

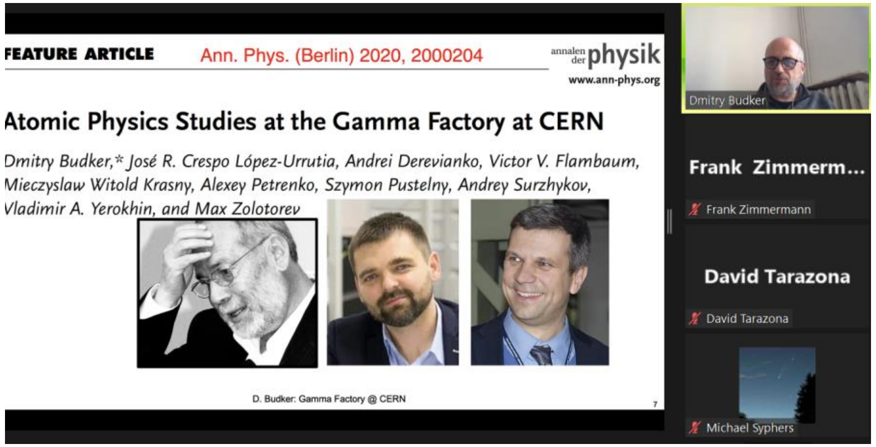




Experimental setup of laser cooling at the GSI ESR

Danyal Winters, GSI

Sessions 4+7 both covered Gamma Factory



Dima Budker, JGU & UCB

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

WP5 milestones

MS15	International workshop on muon source design	5.1	M18
MS17	**Beam requirements for dark-sector searches**	**5.2**	**M18** **Oct. 22**
MS18	**Present and future AI accelerator applications**	**5.2**	**M24** **May 23**
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**

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)

different from a zoom meeting

but need to be careful in shady streets (brazen thefts !)

BSW22 Conclusions - Dark Sector Accelerators

- need to pursue ***tool-driven revolution in science***
- ***EIC is on the way*** – will help unravel QCD mysteries
- ***SHIP, FPF, GF, and FCC-ee are promising for dark sector***
  - decision on SHIP and FPF needed within a year
- ***distant forward detectors*** at all future high-energy colliders ?!
- we recommend studies of ***dark sector reach for DIMUS and for GF-μ source + plasma-based μ source & accelerator***
- ***dielectric acceleration interesting approach for dark sector searches, DLA acc. design & experimental demo required***
- ***EDM ring*** : in-depth studies including prototype ring recommended
- GF-driven subcritical reactor & waste transmutation
  → ***autonomous (self-powered) accelerators***
- next HEP collider ? – ***how complex can or should it be?***

BSW22 Conclusions - Machine Learning

- ***Machine Learning already widely contributes to exploitation*** of operating accelerator facilities – dozens of successful developments at CERN, DESY, FNAL, LANL, PSI and SLAC
- we ***expect that ML will become a standard***
- ML should be used for ***design optimization of future machines***
- ML should be standard topic in ***accelerator education***
- ML could be ***instrumental for dark sector beam performance***
- further work is needed on ***time-varying systems***
- additional benefit or special applications for ***quantum computing?***
- seek ***collaborations with ML experts from other sectors***
- we ***recommend testbed for self-controlling complex accelerator***
- ***how far can we go ?***

iFASTSMART PAF (5.2) - *next steps*

1. Dielectric accelerator for HEP applications, esp. dark matter searches, e.g. single e- acceleration to 20 GeV

- motivated by BSW22 conclusions
- PSI, EPFL, CERN, SLAC; EPFL global leader PhD thesis program + iFAST

2. Joint workshop with iFAST WP11 (Sustainable Concepts)?

- more energy efficient e^+ sources
- energy efficient dark sector accelerators
- energy efficient search for gravitational waves with accelerators ?

3. Joint workshop with iFAST WP6 (Novel Concepts)?

- dark sector reach for plasma-based μ source & accelerator
- machine learning for high-gradient accelerators ?