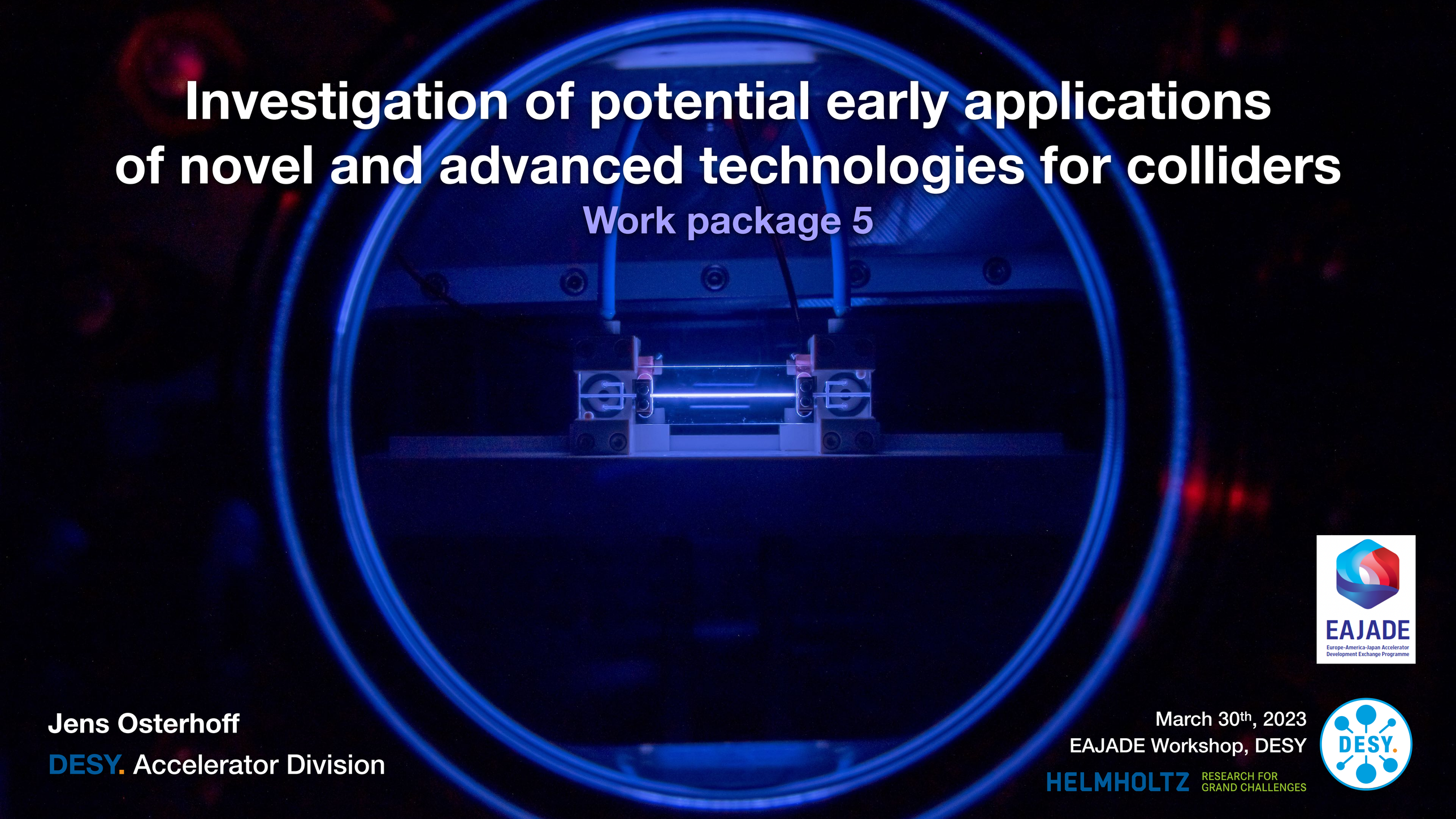
Investigation of potential early applications of novel and advanced technologies for colliders

Work package 5



Jens Osterhoff

DESY. Accelerator Division

March 30th, 2023

EAJADE Workshop, DESY

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

DESY.

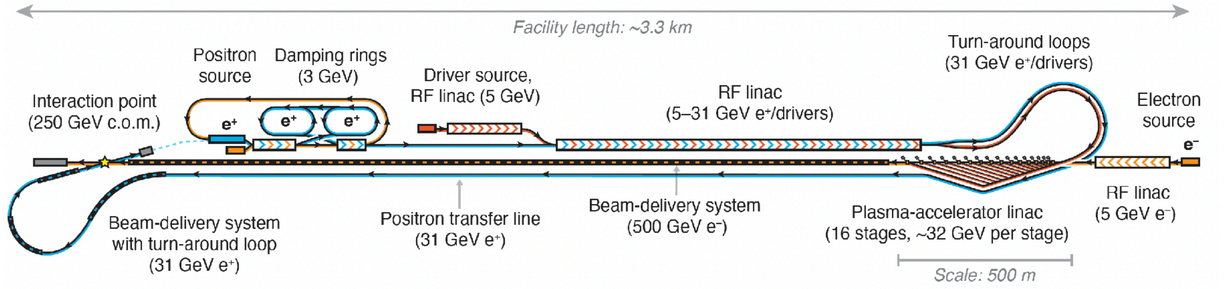
EAJADE will deepen existing collaborations and create new ones

Goal is to strengthen the transatlantic and European work on plasma accelerators for particle physics

Work package 5	Plasma wakefield technologies		Start/end month		1/48	
Work package title	Investigation of potential early applications of novel and advanced technologies for colliders					
Lead beneficiary	DESY					
Participating organisation short name**	DESY	CNRS	INFN	UOXF		
Total person-months per participating organisation:	33	1	10	8		

Objectives

- Investigate the potential of plasma technology for **improved particle collider designs** including **efficiency-maximized plasma accelerator modules** and **positron acceleration.**
- Develop highly-optimized open-source **simulation codes** for **start-to-end study of plasma-based or plasma-augmented particle colliders.**
- **Train Ph.D. students and postdocs** on topics of experimental and theoretical plasma accelerator science.



A Hybrid Asymmetic Linear Higgs Factory (HALHF)

Brian Foster (UOXF/DESY), Richard D'Arcy (DESY/UOXF), Carl Lindstrøm (U Oslo/DESY)
arXiv: 2303.10150 (2023)

Severin Diederichs (DESY) defended his PhD thesis "summa cum laude" on **plasma-based positron acceleration** on March 21st.

Here: together with his supervisors C.B. Schroeder (LBNL) and J. Osterhoff (DESY)

As a result, experiments at SLAC are proposed.

Task 5.1 — Plasma accelerator concepts for future high-energy physics applications

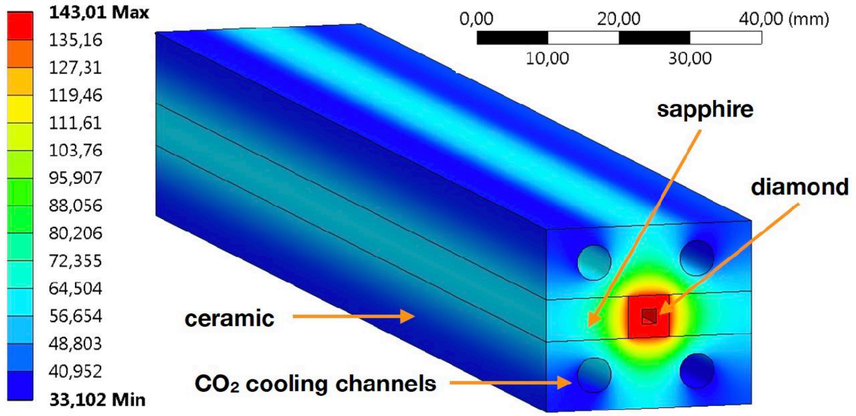
DESY, INFN, CNRS, UOXF — 22 person months

> **Development of novel concepts for solving open challenges in the application of plasma-based accelerators to particle physics**

- high-efficiency and collider-beam-quality **positron acceleration scheme,**
- beam polarization maintenance,
- **high repetition rate/high-average power** support,
- beam-quality-conserving plasma staging.

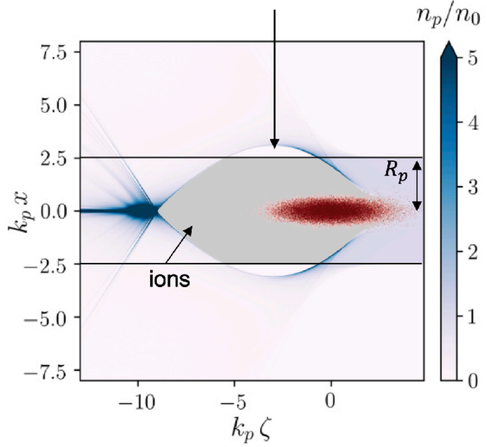
> Secondments to LBNL and DESY.

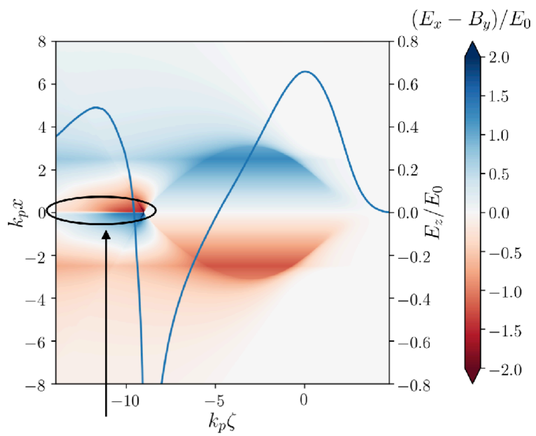
Actively cooled plasma sources



Positron acceleration in a plasma column

1. No ions outside the column





4. Accelerating and focusing fields for e^+

$0.5E_0 \approx 15$ GV/m at $n_0 = 1{\times}10^{17}\ cm^{-3}$

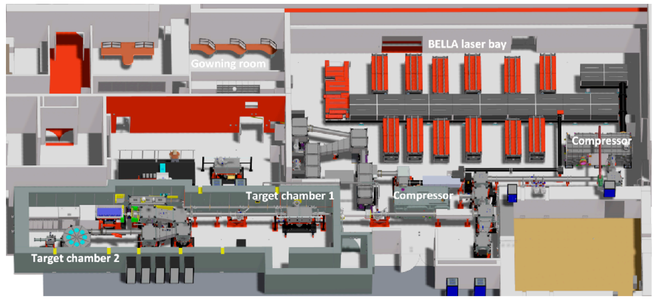
Diederichs *et al.*, PRAB 2020
Diederichs *et al.*, PRAB 2022

Task 5.2 — Experimental plasma accelerator tests

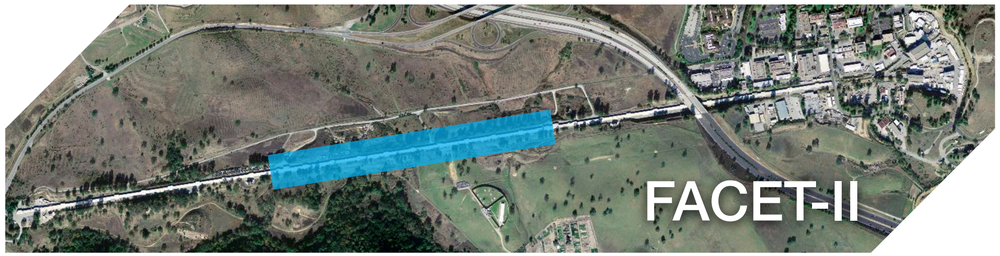
DESY, INFN, UOXF — 19 person-months

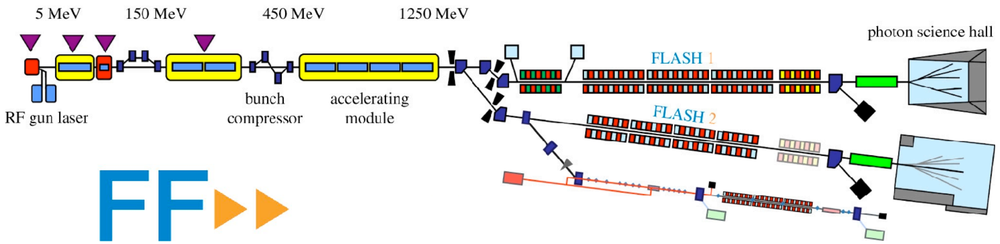
> **Experimental tests of novel concepts of plasma accelerator technology for particle physics applications**

- positron acceleration,
- accelerator efficiency maximization,
- beam quality optimization,
- machine learning controls,
- plasma lens technology.



BELLA





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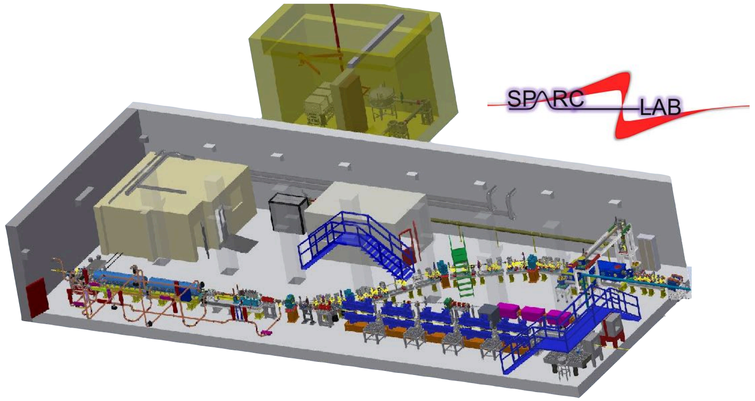
> The to-be-utilized experimental facilities are **FLASHForward** at DESY, **BELLA** at LBNL, **SPARC_Lab** at INFN, and **FACET-II** at SLAC

> This task connects many **leading experimental facilities in the field** and is of highest importance for **cross-fertilization** and the **training of students and postdocs**

> Secondments to LBNL + SLAC, UOXF, INFN and DESY.



Task 5.3 — High-performance computing: development of optimized simulation codes

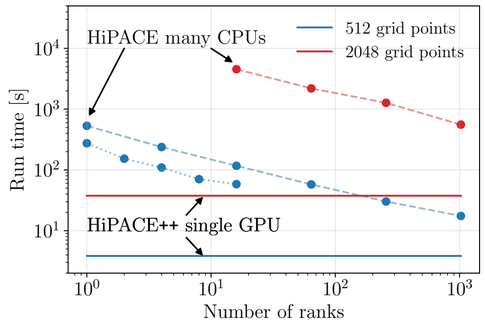
DESY — 11 person-months

> **Development of highly optimized, scalable, and portable open-source simulation codes for full start-to-end calculations of future plasma-based or plasma-augmented particle colliders including tolerance studies.**

> Such tools are currently unavailable and critical for realistic future designs.

> Strengthens the training in modern methods for high-performance computing, machine learning, and code development.

> Secondments to LBNL.

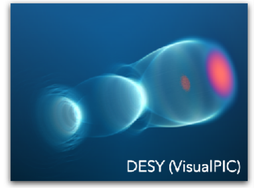


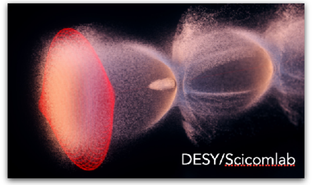
- 10× faster
- 1000× less costly
- scales well to hundreds of GPUs

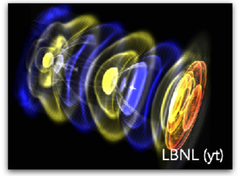
→ OoMs more simulations per $
→ High-res simulations in minutes
→ Production runs on a laptop

DESY/UHH/LBNL develop a portfolio of open-source, high-performance codes for plasma accelerator emulation

	Quasistatic	Fully electromagnetic
Quasi-cylindrical	**Wake-T (DESY)** → Conceptual designs (sec-min) Open-source https://github.com/AngelFP/Wake-T	**FBPIC (LBNL + UHH)** → LPA with injection Open-source GPU https://github.com/fbpic/fbpic
3D	**HiPACE++ (DESY + LBNL)** → 3D external injection Open-source GPU https://github.com/Hi-PACE/hipace	**WarpX (LBNL + many incl. DESY)** → LPA with injection Open-source GPU https://github.com/ECP-WarpX/WarpX



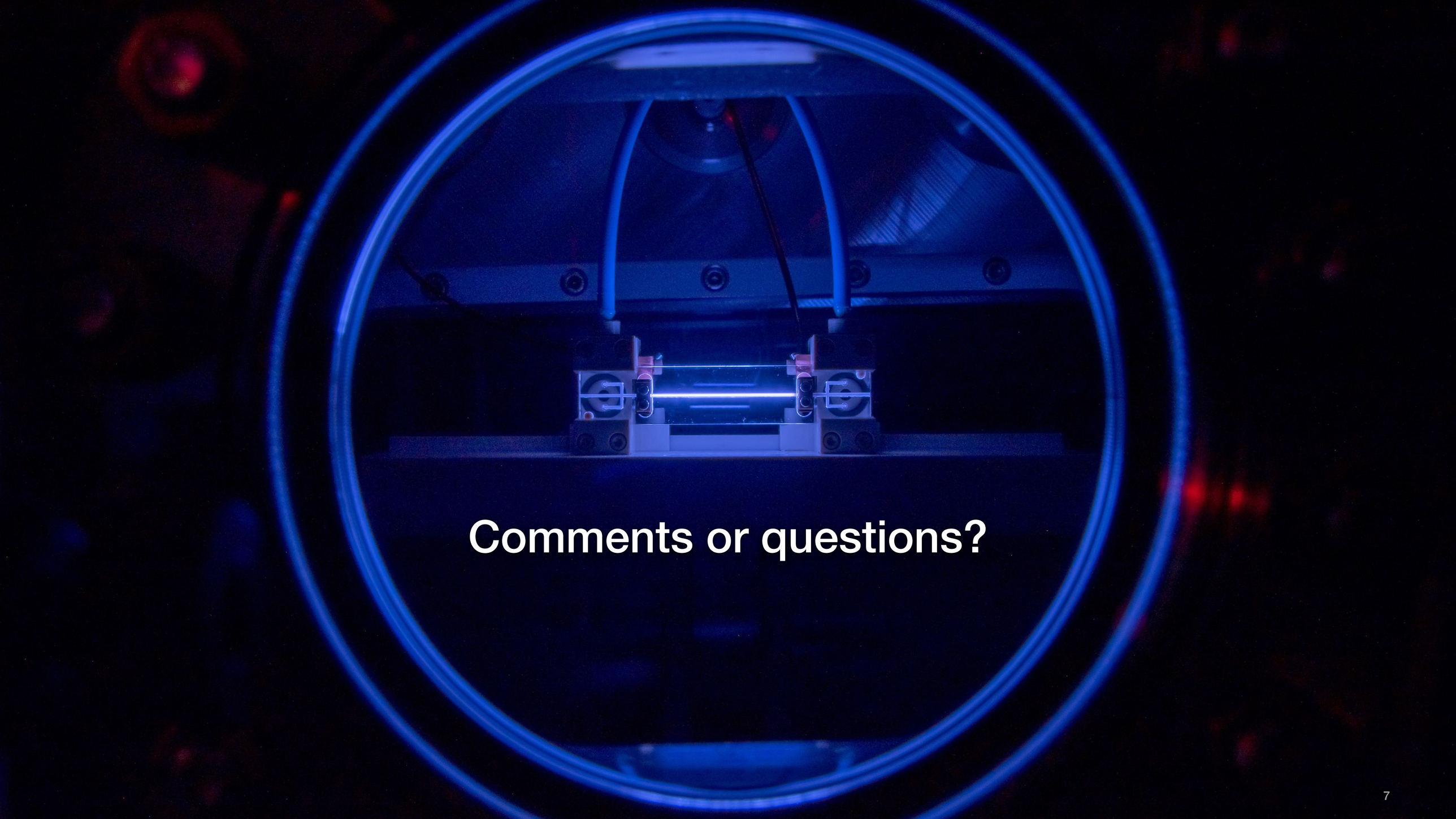




Game changer → Parameter scans instead of single runs in full 3D
Prerequisite for accelerator design

Our deliverables

- **5.1 PosAccPWARep** (month 24, tasks 5.1, 5.2):
  Report on concepts for positron acceleration in a plasma accelerator-based collider
  and on active plasma lenses for efficient positron capturing.
- **5.2 PWAFinRep** (month 46, tasks 5.1, 5.2):
  Report on plasma accelerator module design in the context of concepts for high-repetition rate
  and high-average power acceleration, staging, and beam-quality and natural efficiency limits.
- **5.3 SimCodeFinRep** (month 48, task 5.3):
  Report on simulation code development and the role of machine learning-based optimization techniques
  for full-start-to-end simulations of a plasma-based collider; the report includes details on training progress
  for Ph.D. students in the therefore required software architectures and concepts.



Comments or questions?