Simulations and Plans for possible DLA Experiments at SINBAD.

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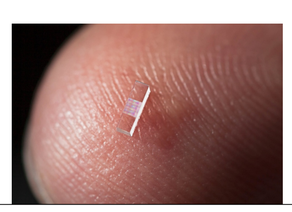
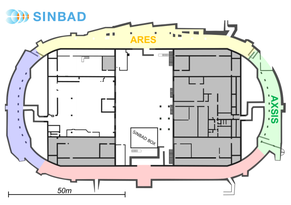
Introduction

- The Accelerator on a CHip International Program (**ACHIP**) aims to demonstrate a working prototype of a particle accelerator on a chip until 2021
- DESY will conduct related test experiments at its **SINBAD** facility (**ARES linac**)
- **Funded by the Gordon and Betty Moore Foundation**

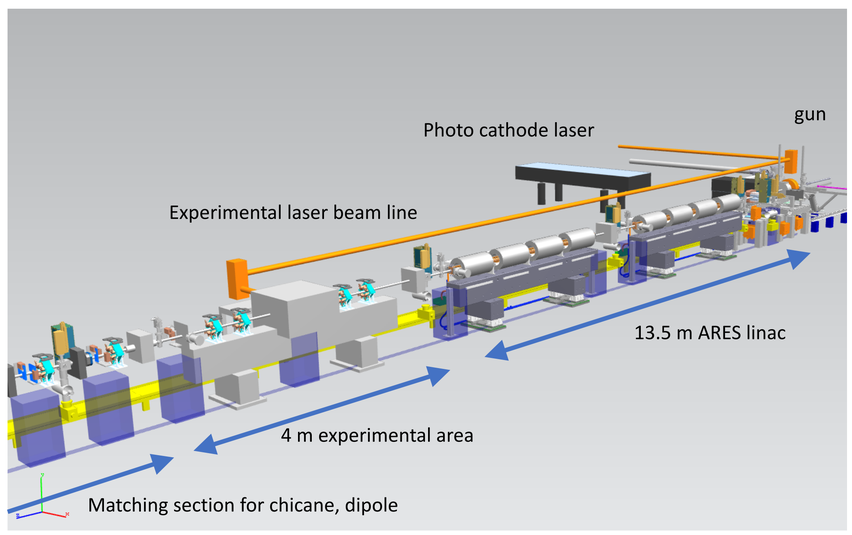
- **Three experiments have been internally proposed to be started mid 2019**
  - External injection of relativistic ultra-short single bunches into a grating-type DLA
  - Longitudinal bunch diagnostics using a DLA-based transverse deflector (design ongoing)
  - External injection of relativistic phase-synchronous optical scale microbunch trains

- Typical **DLA parameters**
  - 2 micron period length → < 1.5 fs acc. buckets
  - sub micron sized channel width





ARES Linac and Experimental Area



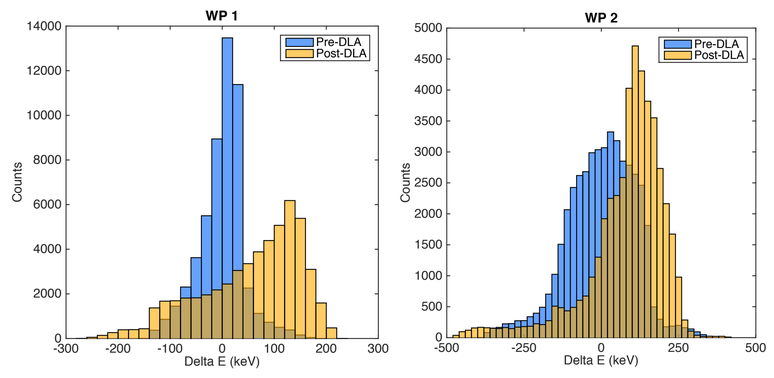
External Injection of Ultra-Short Single Bunches

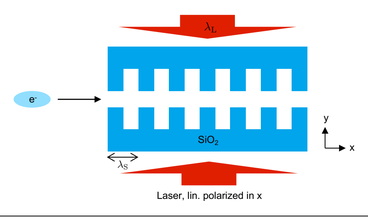
- **Goal**: Show net-acceleration with low energy spread growth instead of modulation
- **Challenge**: DLA structures with periodicity of 2 microns require ultra-short bunches
- **Ideally**: $\sigma_\phi < \pi/4$

- **Possible ARES working points have been identified, almost reaching that goal using velocity bunching @ 500 fC**

- ARES working point without additional focusing (just solenoids)
- Beam is collimated just upstream of the DLA
- Simulations performed with ASTRA and VSim 7.2 (DLA interaction)

- **Results show that the bunches are already short enough to accelerate an ~80% fraction**
- **Simulated energy gain over 30 periods would correspond to ~2 GeV/m acc. gradient**

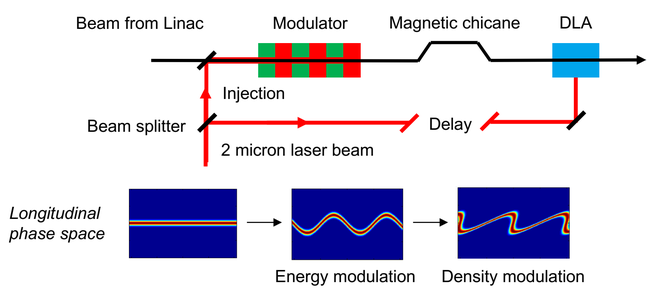




Parameter @ IP	WP 1	WP 2
Charge [pC]	0.05	0.5
Bunch Length [fs, FWHM]	1.8	2.1
E [MeV]	87.6	99.1
ΔE/E [%]	0.05	0.12
σ_{xy} [μm]	6.2	7.8
$\epsilon_{n,xy}$ [nm]	104	105

External Injection of Phase-Synchronous Optical Scale Microbunch Trains

Beam Conditioning Scheme

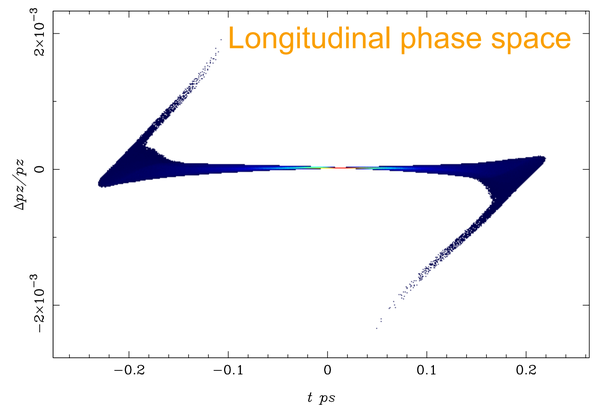


Basic representation of the microbunching scheme using a modulator and a chicane. Note that both the **modulator and the DLA are driven by the same laser**.

Simulated ARES Working Point for Microbunching

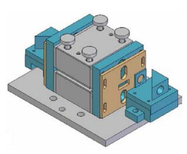
Optimized for minimal energy spread and chirp. Obtained using ASTRA including space charge.

Parameter @ Mod	Value
Charge [pC]	2.5
Bunch Length [fs, rms]	112.3
E [MeV]	75.26
δ	$0.76 \cdot 10^{-4}$
$\epsilon_{n,xy}$ [nm]	248

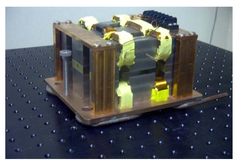


Microbunching Setup

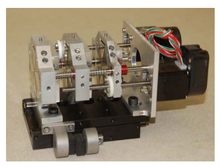
- First feasibility studies using a proposed extension of ARES can be found in [1]
- **Here**: Simulations based on equipment used in [2]



Undulator



Chicane



PMQ Triplet

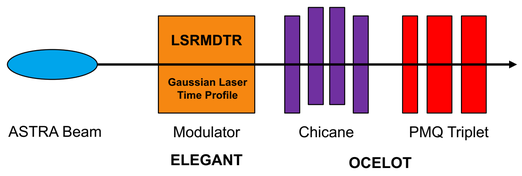
Mod Parameter	Value
Undulator Period [cm]	1.8
Periods	3
K	0.46-1.7

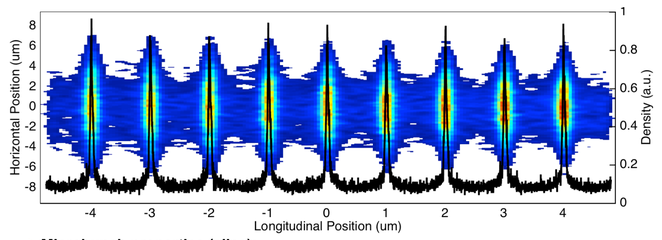
Chicane Parameter	Value
R56 [mm]	0.06-0.22

PMQ Parameter	Value
Bore Radius [mm]	3
Magnet Length (1) [mm]	7
Magnet Length (2,3) [mm]	13
Spacing (adjustable) [mm]	4-20
$B_{max,pole}$ [T]	0.6

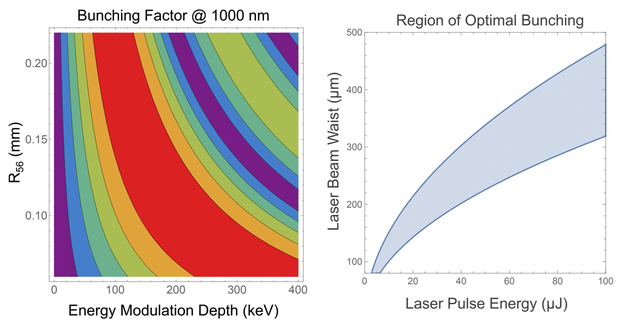
ELEGANT + OCELOT Simulation and Optimization

- The undulator was designed for 800 nm, 60 MeV
- We study microbunching at ~1 micron (due to available laser system) → At 1 micron the resonant energy is ~75 MeV
- Laser modulator via ELEGANT, all other elements via OCELOT incl. space charge and CSR

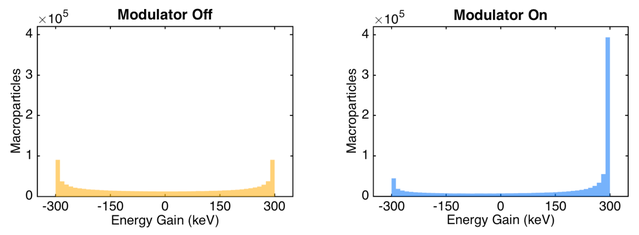




- **Microbunch properties (slice):**
  Spacing: (1.0011±0.0068) μm, Length: (161±13) as, FWHM
- **Microbunch properties (full bunch):**
  Spacing: (1.0002±0.0091) μm, Length: (186±73) as, FWHM



DLA Interaction after Final Focus



> Clear enhancement of the acceleration efficiency!

[1] F. Mayet et al., *A concept for Phase-Synchronous Acceleration of Microbunch Trains in DLA Structures at SINBAD*, Proceedings of IPAC'17 Copenhagen, WEPVA006
[2] C. Sears, *Production, Characterization, and Acceleration of Optical Microbunches* (2008), Dissertation

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