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SINBAD

***S**hort **IN**ovative **B**unches and **A**ccelerators at **D**ESY*

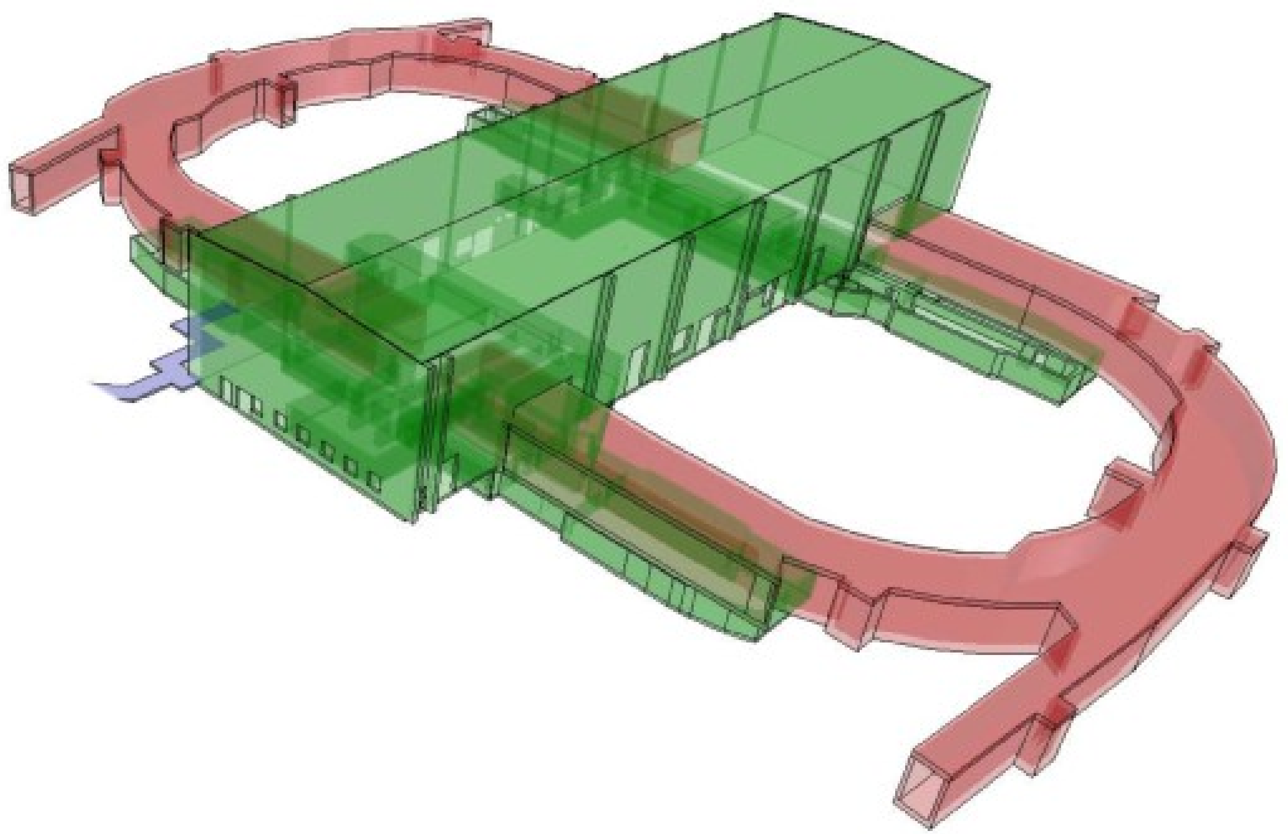
LAOLA. collaboration meeting
06.10.2014

The Idea:

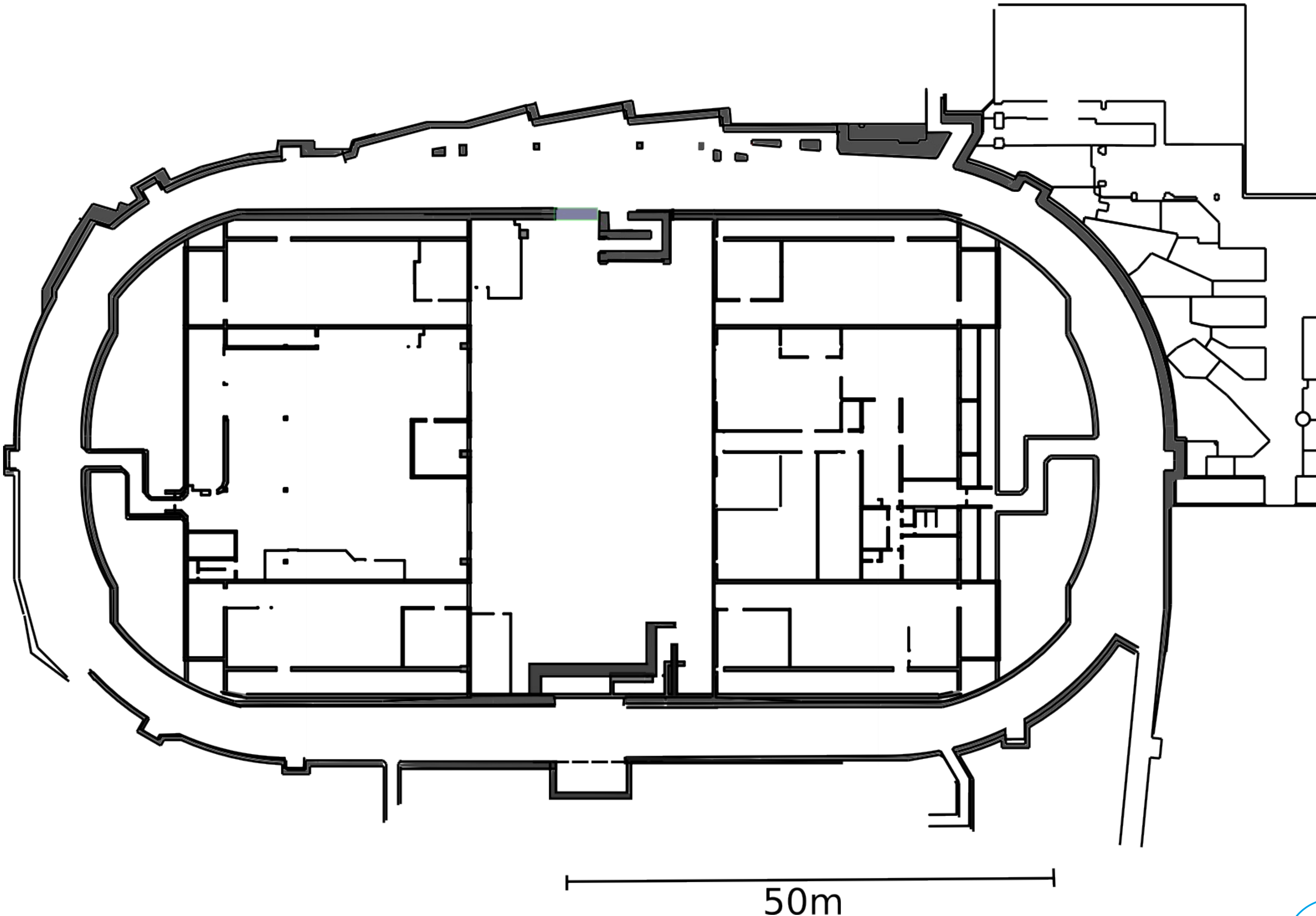
- Turn the DORIS storage ring plus central halls into a multi-purpose accelerator R&D facility with several experiments from ultra-fast science and high gradient accelerator modules.
- Based e.g. on the ongoing LAOLA activities, it is intended to provide a space for long-term dedicated accelerator R&D with multiple experience using a common infrastructure.
- Upgrades/extensions will hopefully be funded via Helmholtz strategic infrastructure investment funds.
  - Together with 6 other Helmholtz centers, we are working on a proposal called “distributed ARD test facility”
  - With the dARDTf, it is intended to become one of the two “Leuchtturm projects”

Available Location

- DORIS (Building 30)
  - RP-tunnel with 1 – 1.5 m concrete walls
  - Large central hall & infrastructure rooms
- Collecting requirements (space, infrastructure)
- Developing first layouts – still on “lego” level

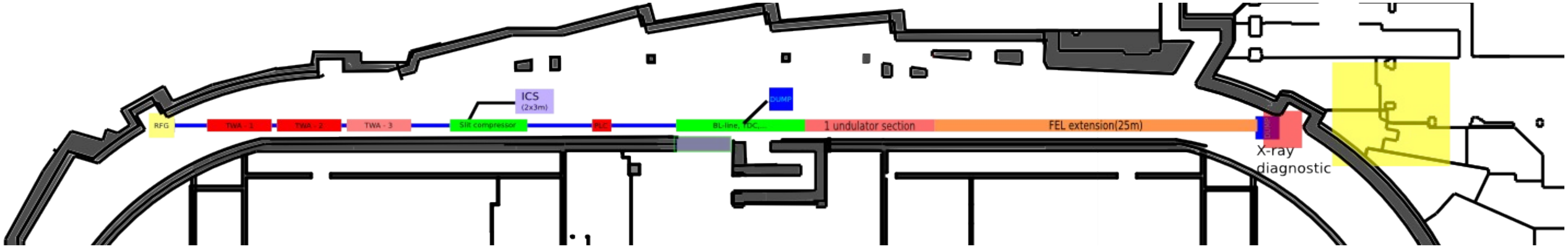


Facility Layout



ARES and Plasma Acceleration

- Staged approach:
  - Construct injector (ARES) for ultra short bunches (100MeV)
  - Plasma acceleration for energy doubling at low plasma densities
  - Increase energy to reach FEL - capabilities



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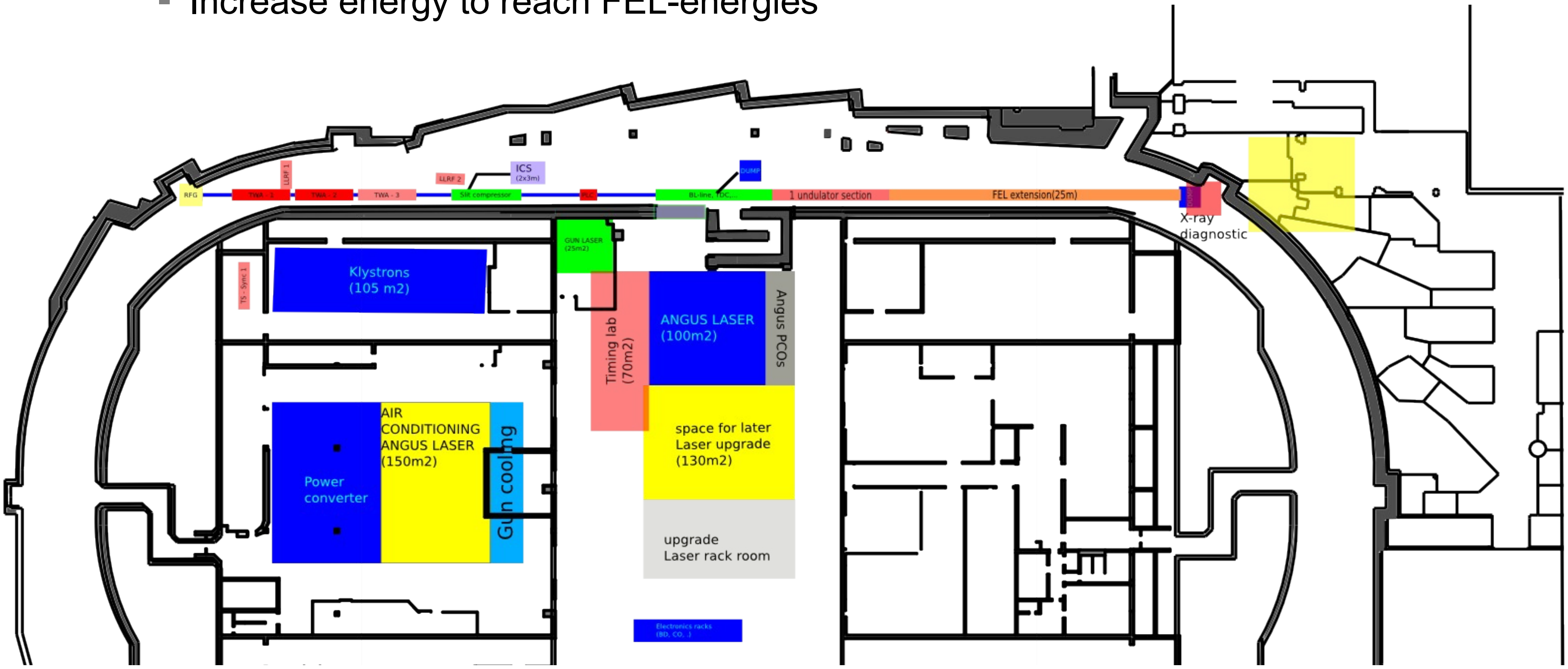
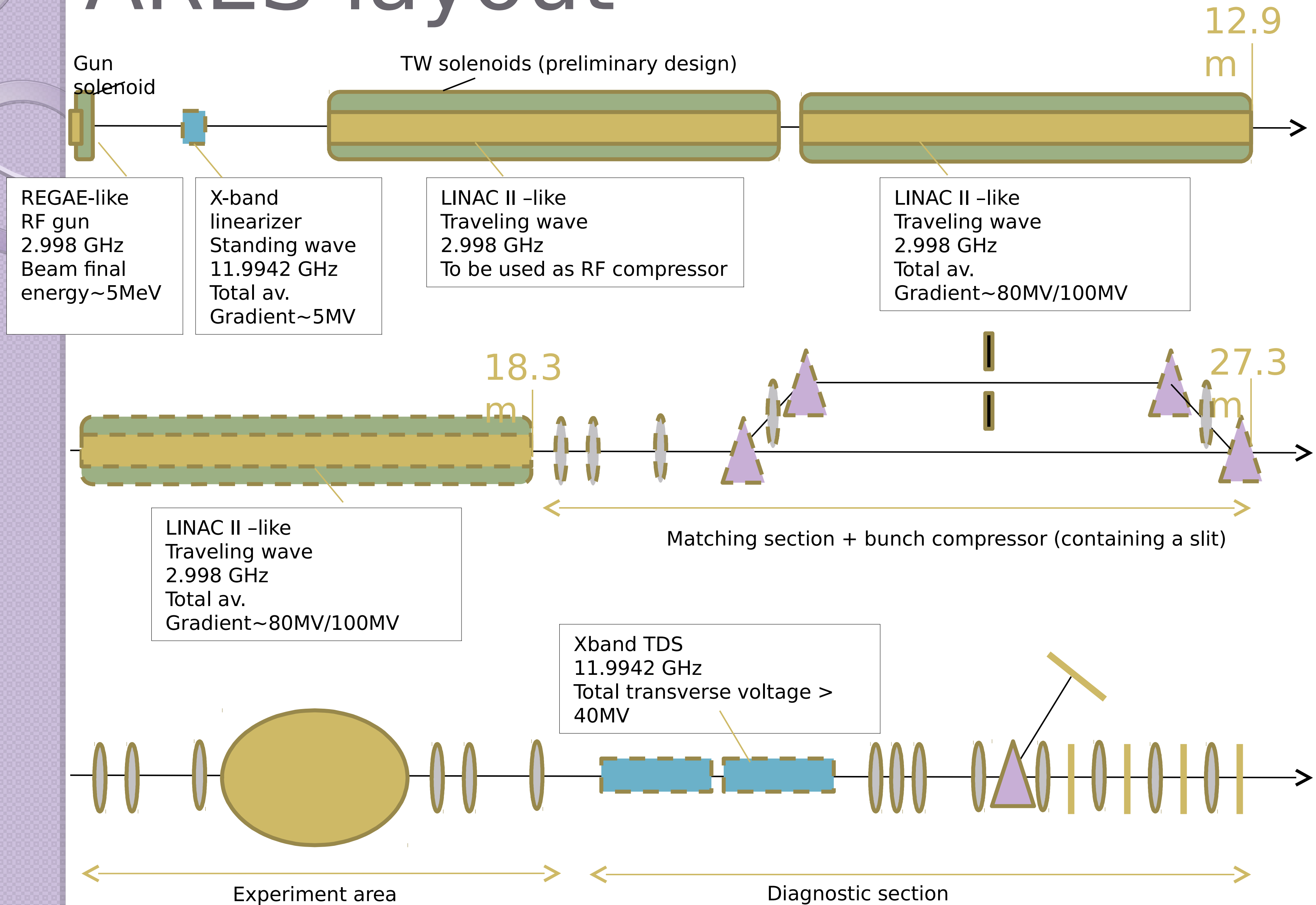


ARES layout

PI: B. Marchetti
LAOLA technical seminar talk, 14th Oct



Beam parameters

Goal parameters for external injection into plasma:
E-bunch energy 100 MeV
E-bunch length ≤ 1fs
Arrival time jitter ≤ 10 fs
Transverse position jitter ≤ few μm

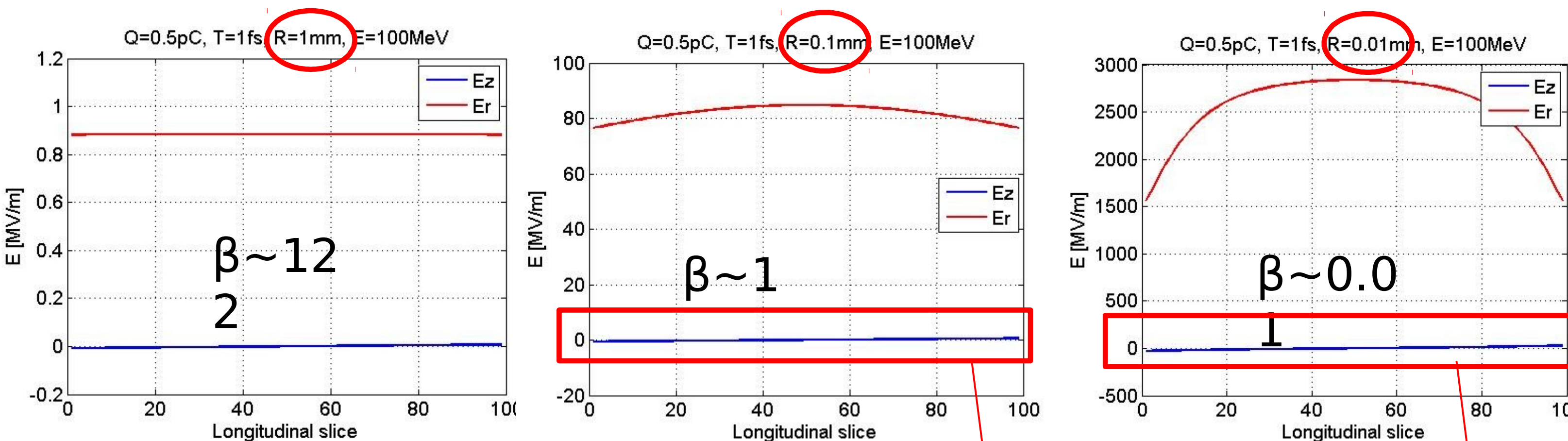
Energy upgrade for Compton scattering experiment:
E-bunch energy 150-200 MeV

Other e- beam parameters:

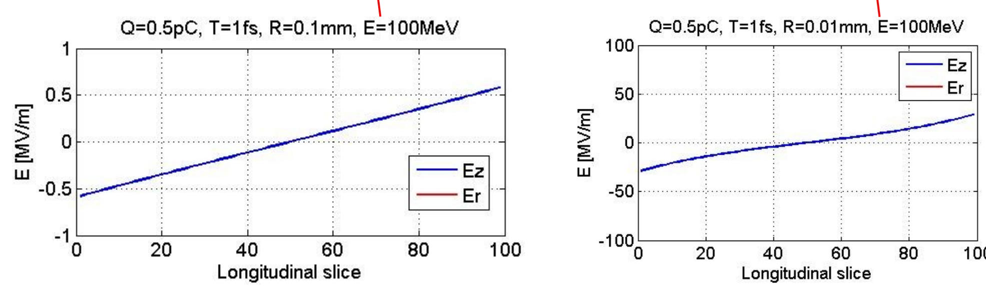
Charge: 0.2-20 pC
Energy spread: 0.1-0.4 %
Transverse emittance < 0.5 mm mrad

Challenges

- Manage the e-bunch decompression due to the space charge force during the transport of the beam, its characterization and its focusing at the plasma chamber.



Emittance x/y~0.1 mm mrad



Challenges 2

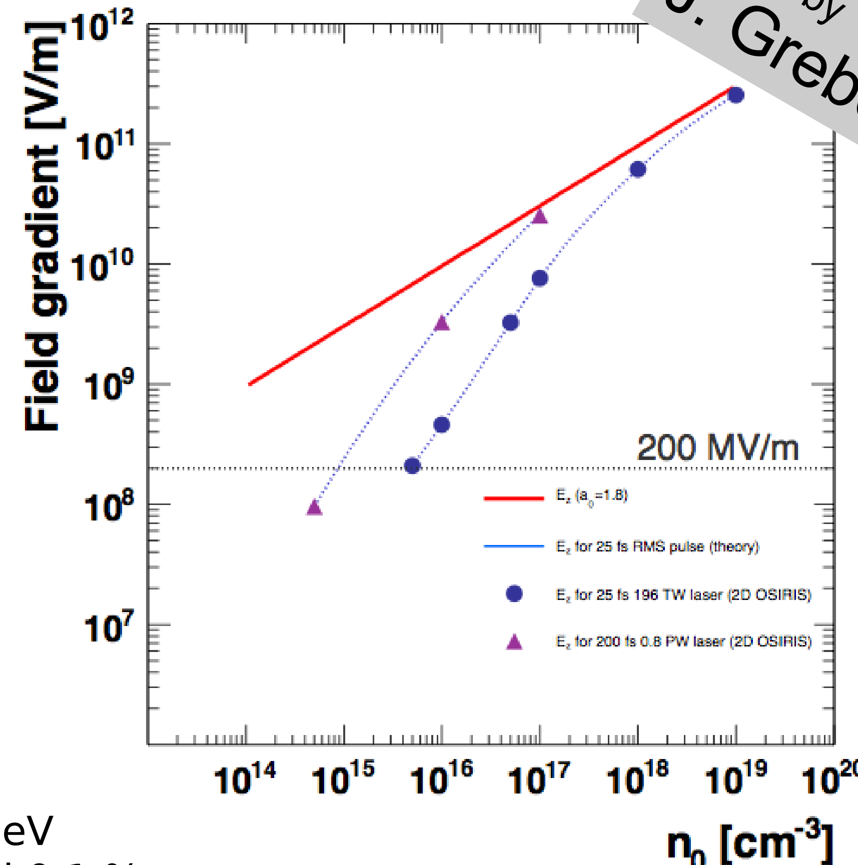
- Manage the e-bunch decompression due to the space charge force during the transport of the beam, its characterization and its focusing at the plasma chamber.
- High stability requirements (beam arrival jitter, final bunch length jitter, energy jitter).
- The feasibility of the linearization of the phase space using an X-band cavity has to be proven (small aperture, strong wakes, tight tuning of the gun solenoid).
- The slit method has never been pushed before to a so short final bunch length.

Plasma acceleration at Sinbad

Slides by J. Grebenyuk

Laser-plasma acceleration with external injection of ultra-short bunches at low densities

- Relaxed requirements on synchronization jitter and transverse tolerances
- Lower gradients but longer maximal acceleration length



3D particle-in-cell (PIC) simulation

Angus Laser
Laser a0=1.8
Pulse length 25 fs FWHM
Spot size 50 microns FWHM
Energy 5 J
Power 200 TW

Bunch
Charge 1 pC
Energy 100 MeV
Energy spread 0.1 %
Emittance 0.3 mm mrad
Length RMS 3-12 microns
Transverse RMS 5 microns

Plasma density of $0.5x10^{16}$ is feasible (gradients of about 200 MV/m)

Goal: Conserve externally-injected bunch quality (minimize induced energy spread and emittance growth inside and after plasma)

Sinbad stages

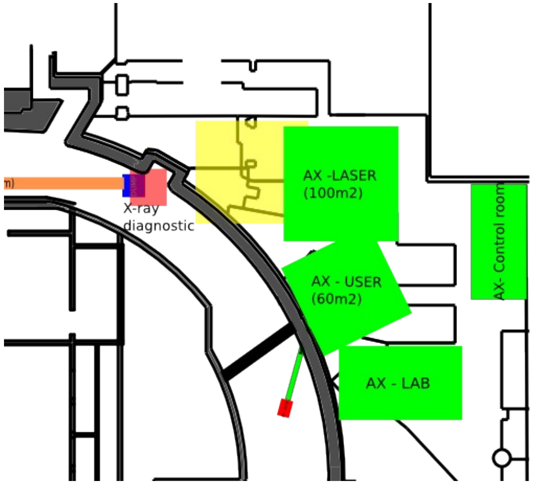
Plasma density [cm^{-3}]	10^{18}	10^{17}	10^{16}	0.5×10^{16}
Injection beam energy [MeV]	100	100	100	100
Laser pulse duration [fs]	25	25	25	25
Field gradient (OSIRIS) [GV/m]	62	7.58	0.46	0.21
Accelerating region, $\lambda_p/4$ [μm]	8.35	26.5	83.5	118
200 MeV stage length [m]	1.6×10^{-3}	13.2×10^{-3}	0.22	0.48
1 GeV stage length [m]	16×10^{-3}	0.13	2.2	4.8
Matched β [mm]	0.1	0.3	1	1.5

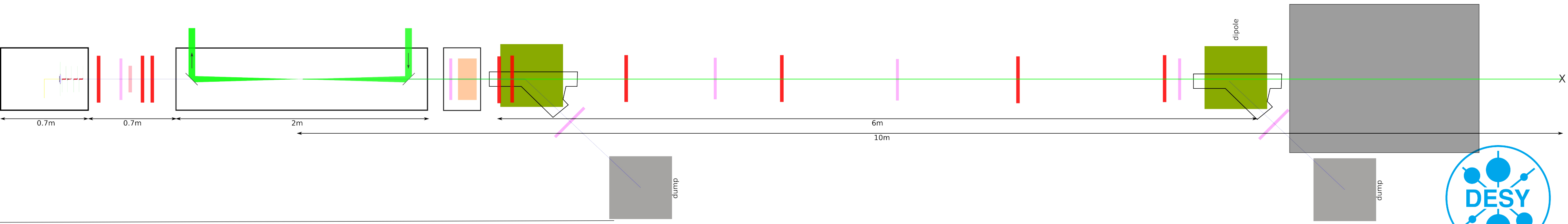
Laser-plasma acceleration with external injection of ultra-short bunches at low densities

- Requires laser guiding to achieve high energies at low densities
- Driver-bunch RMS synchronization jitter requirements: 5 - 30 fs
- When synchronized, energy spread below 1% achievable
- To minimize induced energy-spread growth: RMS < 5 fs bunches desirable
- When matched, no emittance degradation > matching to small beta required (optics + adiabatic)

AXSIS

- Attosecond X-ray Science: Imaging and Spectroscopy
- Collaboration between Hamburg University, DESY & Arizona State University, lead by F. Kaertner
- Goal: Develop a fully coherent attosecond X-ray source based on coherent inverse Compton scattering off a free-electron crystal. (few pC, tens of MeV, few tens of atto-seconds)
- Laser driven dielectric structure
- DESY-M contribution:
  - Beam dynamic simulations
  - The diagnostic beam line
  - Host experiment



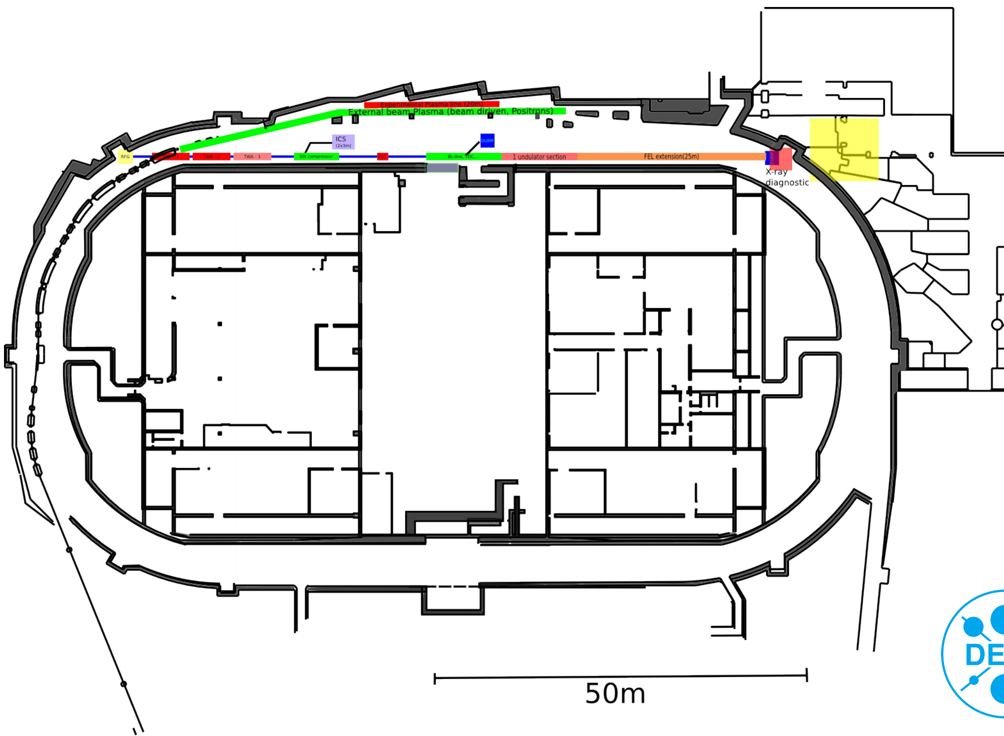


External Beams

- The potential: Transport Beam from Linac 2 to SINBAD in order to
  - Allow beam driven plasma experiments (800MeV electrons)
  - Allow positron plasma acceleration (up to 400MeV positrons)
- The challenges:
  - Find suitable optics given the existing machine layouts to achieve interesting beam parameters (peak current, bunch length)
  - Timing synchronization and RF stability
- Status
  - Still collecting info about existing machines
  - No satisfactory optics solution found yet, still ongoing

Experimental Line

- First multi-use of Laser



DRAFT SCHEDULE

- Until End 2015: Design, preparation studies, start procurement
- 2016:
  - Premises clean up (while X-FEL project completes construction and frees resources)
  - Preliminary AXSIS experimental setup
- 2017:
  - Construction of SINBAD Phase 1
  - Start of first beam studies in ARES-SINBAD
  - Start of AXSIS research program
  - Initial plasma acceleration experiments
- 2020: Complete construction of full SINBAD
  - 4 independent experimental zones
  - Laser upgrade to 1PW ? Installation of second 200TW laser?