A Double Dipole Kicker for ALBA II

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24th April 2023

Ayuda **ICTS-MRR-2021-02-CELLS** financiada por:

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea
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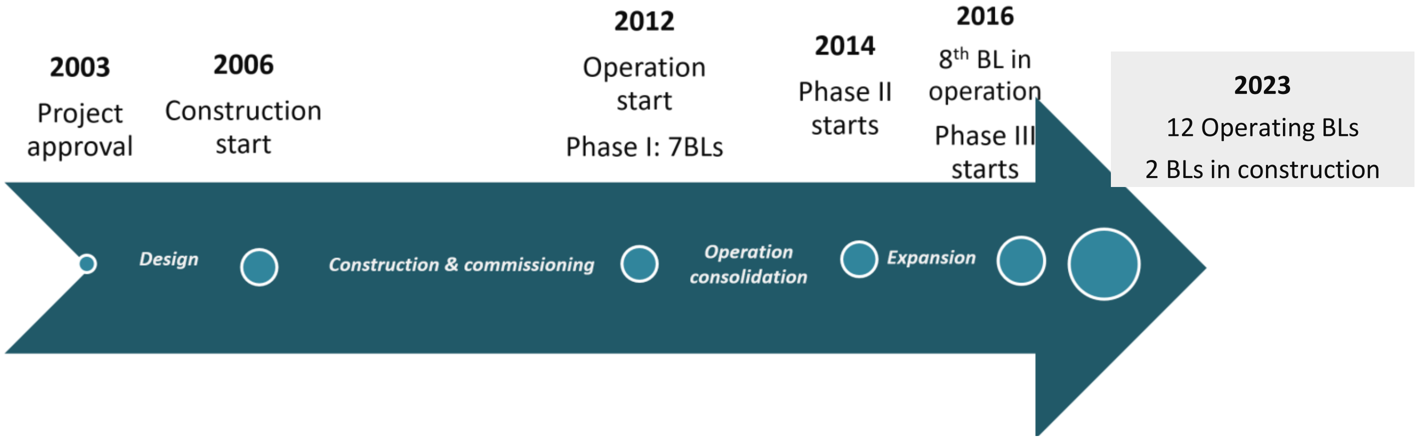
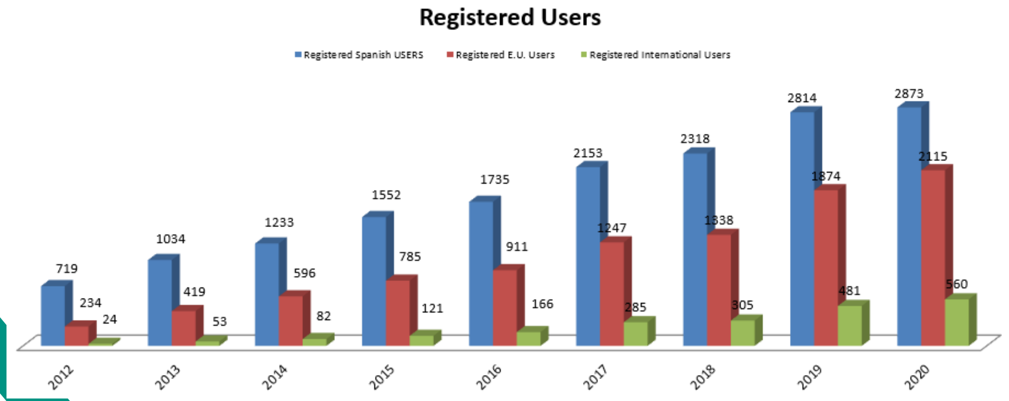
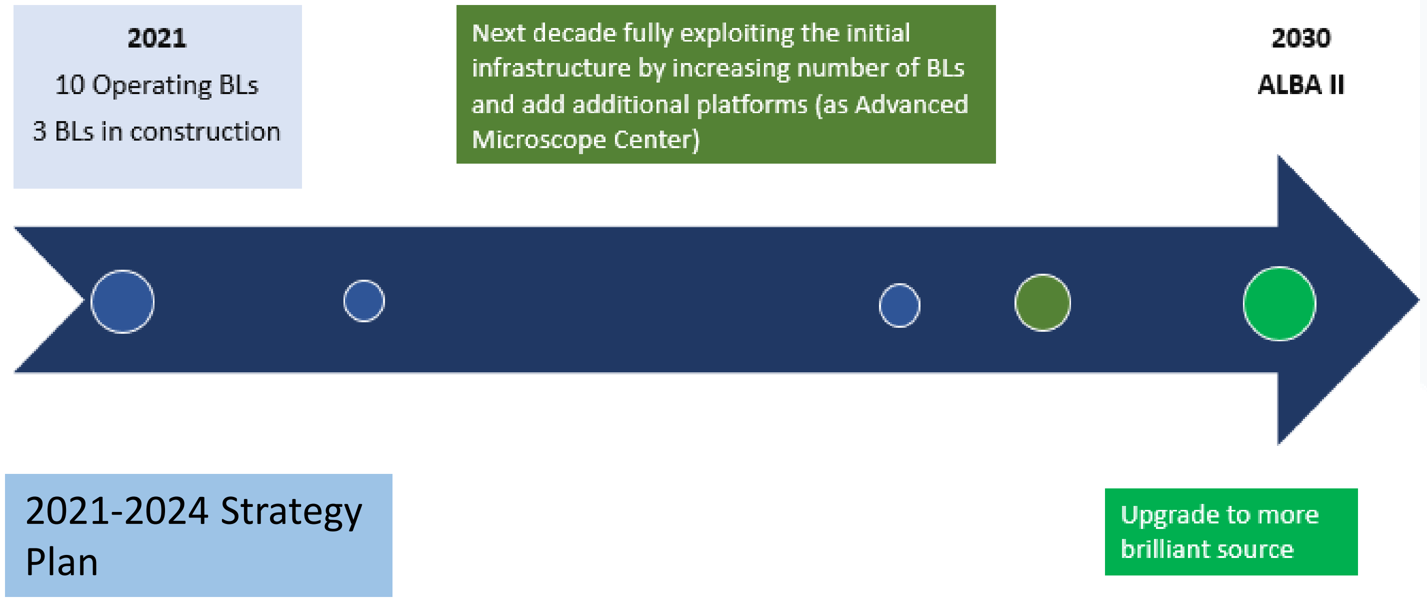
ALBA Synchrotron: History and Future



First proposal for building a synchrotron in Spain: in the '90s

10 Years for the approval - 10 Years up to the operation





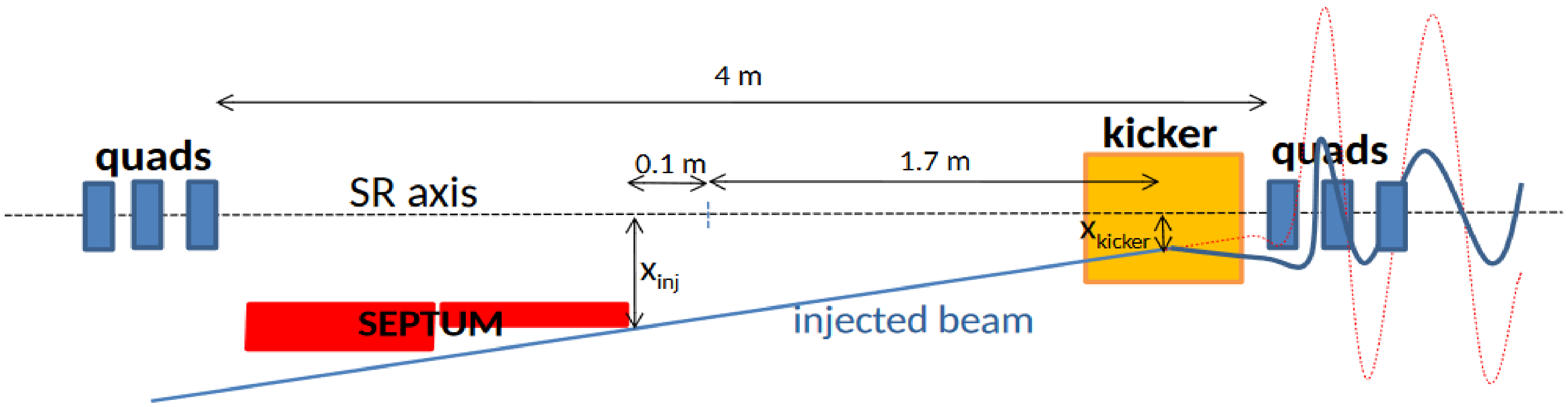
The ALBA II injection scheme

- ALBA II
  - New low emittance storage ring: **180 pm·rad** (factor 25 reduction)
    - Use the same Booster Injector: $\varepsilon = 10$ nm·rad
  - Smaller physical aperture ring
    - Horizontal dynamic aperture reduction: ±20 mm to ±6 mm
  - Very compact arrangement of the magnets
    - Injection straight section reduced from 8 m to **4 m**.

- Injection with a single fast pulsed multipole kicker needed
  - Transparency of injection
  - Reduced number of elements

The ALBA II injection scheme

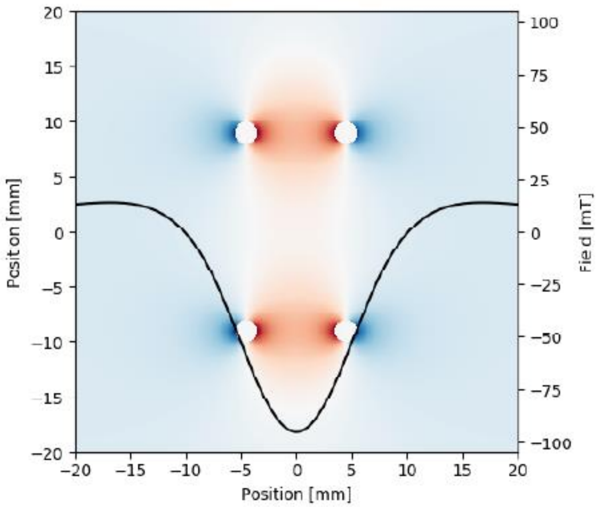
- ALBA-II injection scheme:
  - **Strong & thick septum**: to bring the injected beam to a few cm from the stored one.
  - **Weak & thin septum**: to bring the injected beam in the acceptance region of the kicker.
  - **Multipole kicker** for off-axis injection.
    - 1.75 μs semi-sinus pulse.
  - **Transparent injection** for the users **condition**: $\Delta x < 10\% \ \sigma_x$ and $\Delta x' < 10\% \ \sigma_{x'}$



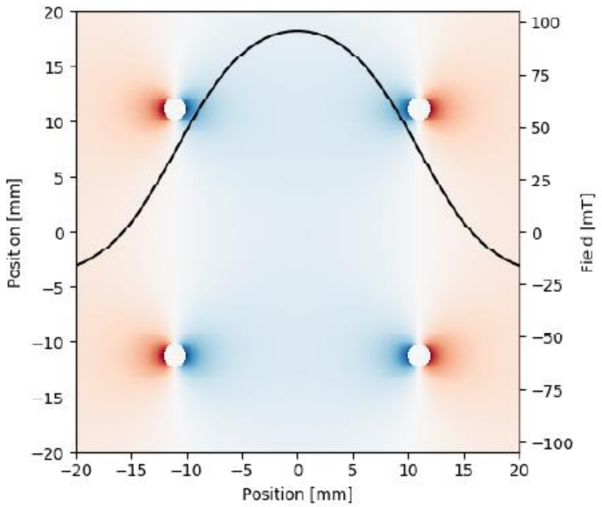
The Double Dipole Kicker topology

4 inner and 4 outer conductor rods create two opposite dipole fields

Inner coils field



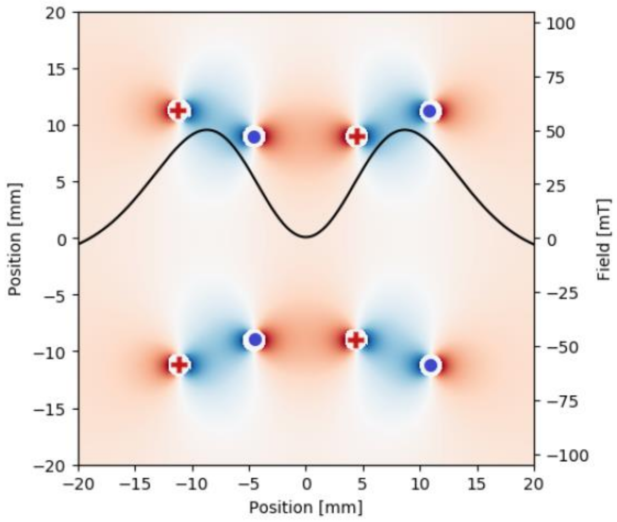
Outer coils field



Only 4 outer rods powered

- Dipole field for on-axis injection
- Useful during commissioning

Superposition of the inner and outer coils fields



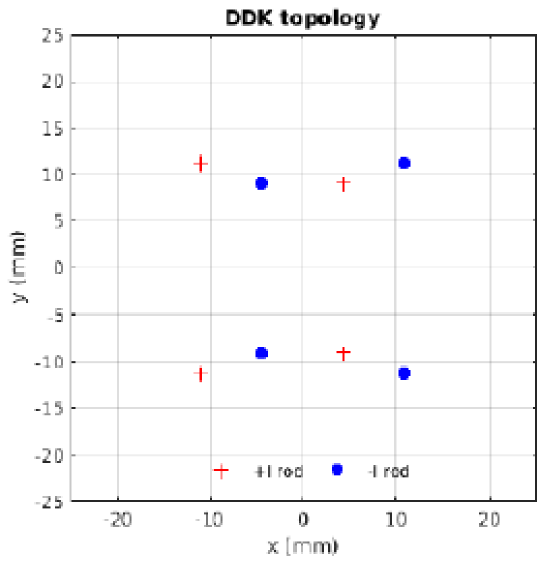
8 rods powered

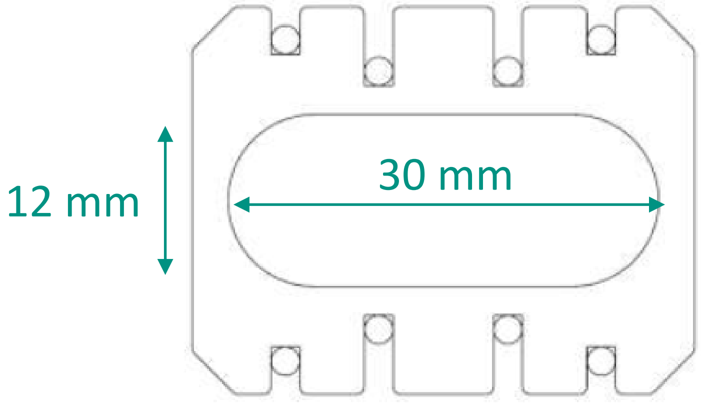
- Zero field at the stored beam
- Field peak at the injected beam

G. Benedetti *et al* 2023 *J. Phys. Conf. Ser.* **2420** 012017

DDK ALBA prototype

- The DDK prototype for ALBA
  - Positioning of the rods calculated in order to:
    - Maximize the kick efficiency in mrad/kA
    - Minimize the disturbance to the stored beam (orbit and emittance)
  - Ceramic chamber with inner Ti-coating layer optimization:
    - Minimize heat losses of the beam image currents
    - Minimize eddy currents induced by the pulsed field.
  - Small vertical aperture
    - Get the field peak at the position of the injected beam.
- For ALBA case:
  - Field peak at x = 8.7 mm (B_y = 50 mT)
  - Ceramic vacuum chamber dimensions:
    - H x V = 30 mm x 12 mm
    - Ceramic length: 300 mm
  - Ø2 mm copper conductor rods





DDK ALBA prototype – Tolerances

- DDK tolerances for transparent injection
  - **Maximum residual field** at stored beam position (according to transparent injection condition):

    $\Delta B_x < 13\ \mu T$ $\Delta B_y < 70\ \mu T$ $\frac{\partial B_y}{\partial x} < 0.36\ T/m$

  - Mechanical tolerance of rod positions (to don't exceed residual field):

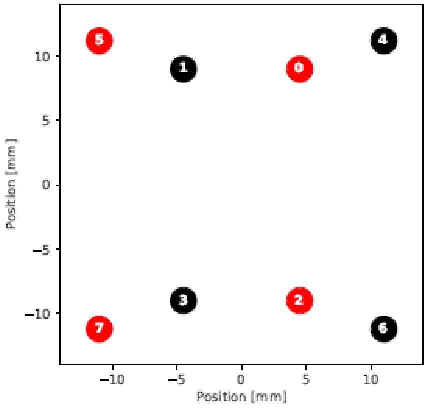
    $\pm$ **1 μm** in both directions → unfeasible

    Realistic is +/- 20 μm → $\Delta x \sim \Delta y \sim \pm \mathbf{200\mu m}$ displacement of the pulse at the stored beam

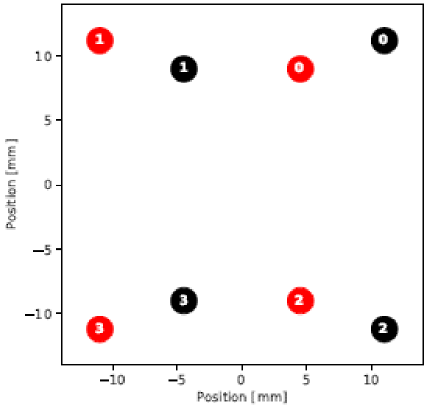
  - **Solution to have zero field at the stored beam**:
    - Make pass the stored beam to the minimum of the pulse.
      - Still a residual field on the stored beam expected of the order of $\Delta B_{x,y} \sim \pm 200\ \mu T$
    - Power the inner and outer coils with **two independent power supplies**.
      - 2 identical pulses. Freedom 2 pulses: delay,amplitude
      - The integral of the difference between the current of the two pulses < 0.12% pulse current value

DDK ALBA prototype – Field error

- Field error estimation due to finite propagation speed of the two pulses
  - Assuming the current pulse propagates at constant speed through conductors.
    - Propagation speed between alumina and vacuum
  - The overall field distortion is affected by the rods connection order.
    - This error can be partially compensated by the use of two independent power supplies.
  - Overall effect on the stored beam estimation from the mean field error for single and double power supply configurations



1 power supply configuration

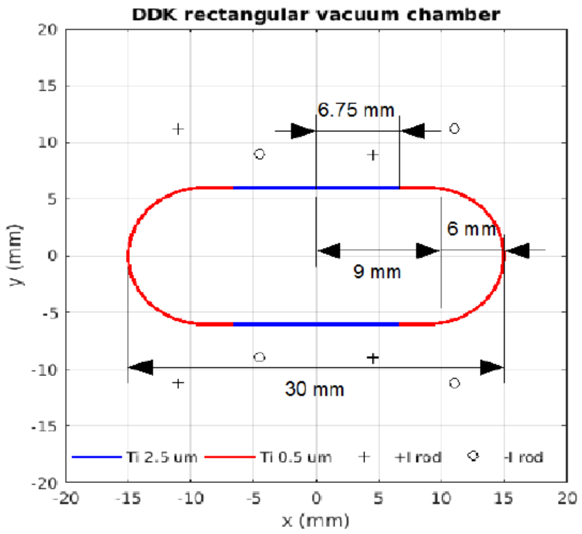


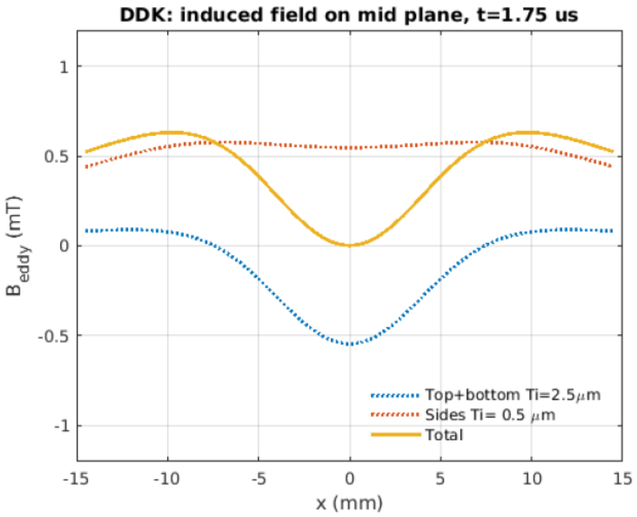
2 power supplies configuration

	Single power supply		Double power supply	
	Vacuum	Alumina	Vacuum	Alumina
ΔB_x	160 µT	475 µT	50 µT	155 µT
ΔB_y	210 µT	630 µT	0	0

DDK ALBA prototype – Coating

- Coating thickness optimization:
  - To minimize power dissipation: at least 1 μm coating thickness needed
- The pulsed field induces eddy currents on the metal coating.
  - Produces a perturbation on the magnetic field profile.
  - Top/bottom walls and side walls produce opposite contributions to the induced field at center.
- Induced field at the center (x,y)=(0,0) can be made zero:
  - By applying **coating 5:1 ratio between top/bottom and side walls**
  - This minimizes the perturbation on the stored beam due to eddy currents.





DDK ALBA prototype – Specs

- magnetic specifications:

Inner rod position	x_i, y_i	4.50, 9.00	mm
Outer rod position	x_e, y_e	11.00, 11.20	mm
Diameter of the rods		2	mm
Field at x = 8.7 mm	B_y	50	mT
Magnetic length	L	300	mm
Total coils inductance	L_{tot}	0.90	µH
Inner coils inductance	L_{in}	0.83	µH
Outer coils inductance	L_{out}	0.55	µH
Mutual inductance	M_{inout}	-0.24	µH

- Half sinus current pulse parameters:

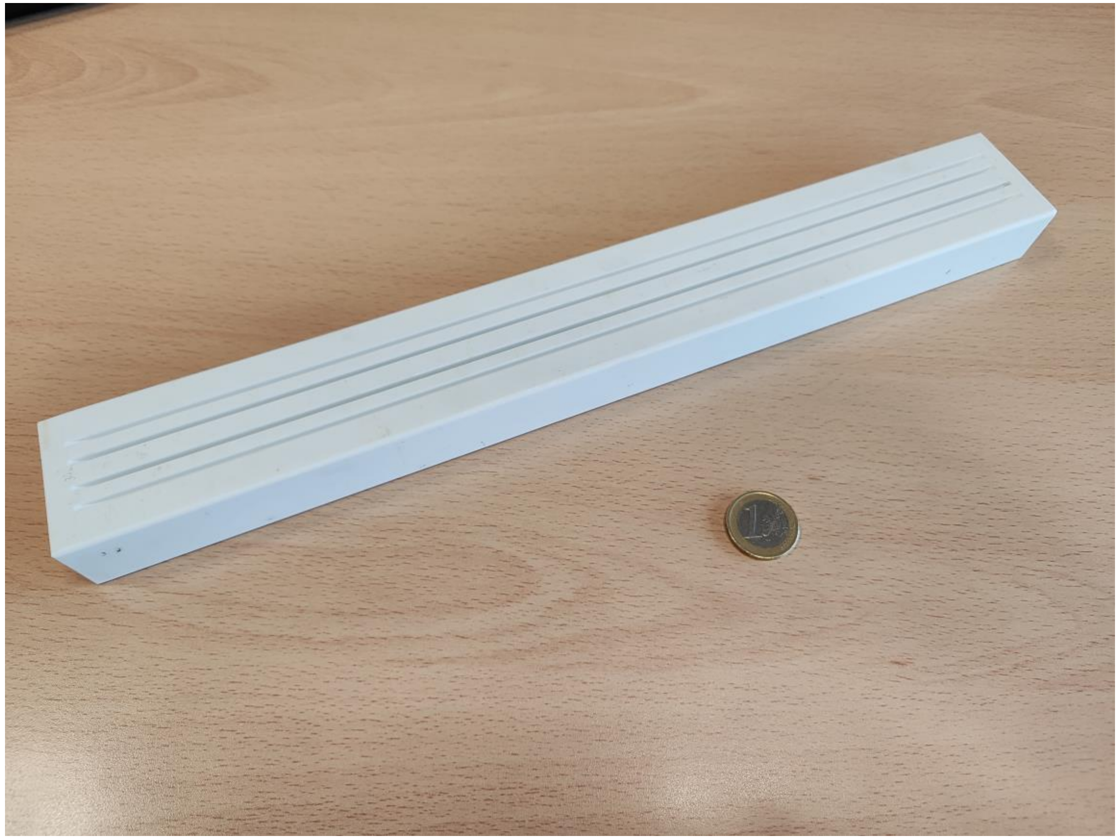
Pulse duration	t_p	1.75	µs
Peak current	I_0	2675	A
Nominal repetition rate	f_{rep}	3.125	Hz

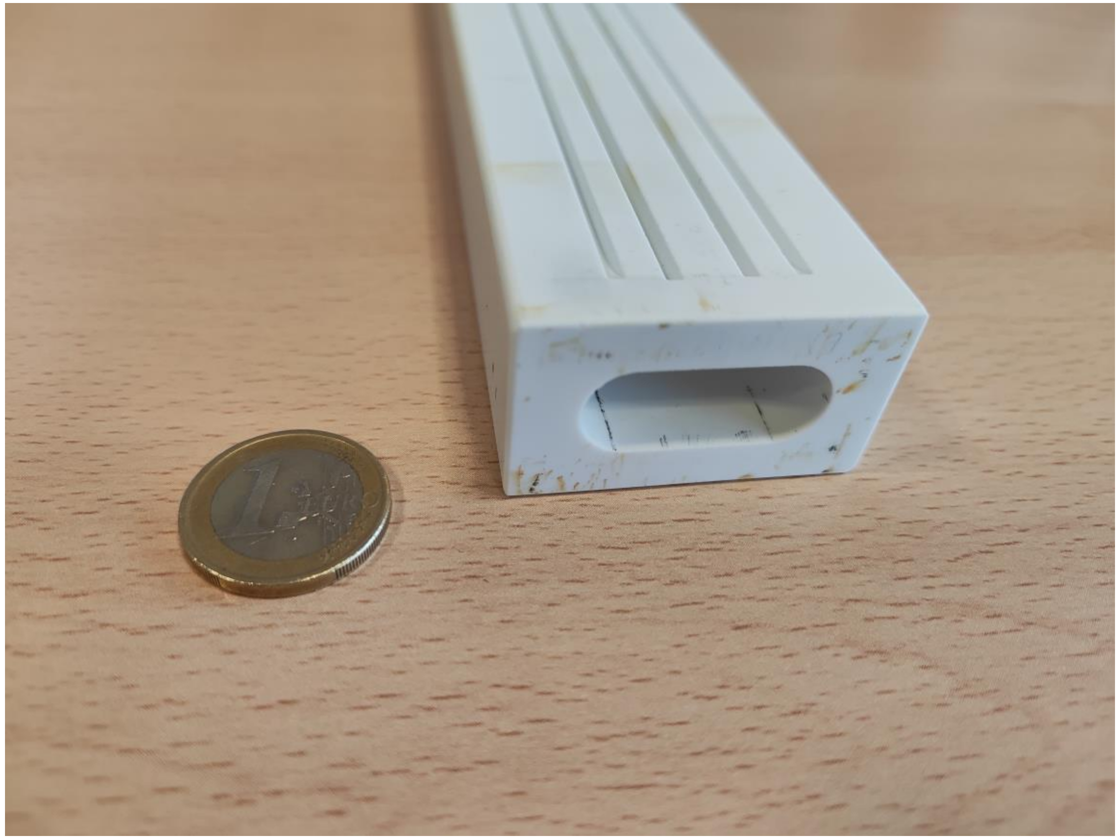
Status and Schedule

- **Tender ongoing**: for the ceramic vacuum chamber and 2 power supplies
  - Delivery: end of 2024
  - DDK installation at ALBA: end 2025 for proof-of-principle

- **ALBA-SIRIUS collaboration** for several NLK related issues:
  - Ceramic manufacturing at Sirius lab according to their know-how experience
  - Metallic coating studies:
    - Eddy current minimization simulations
    - Heat losses reduction simulations
  - Metallic coating technique development at Sirius lab
    - Material deposition simulations

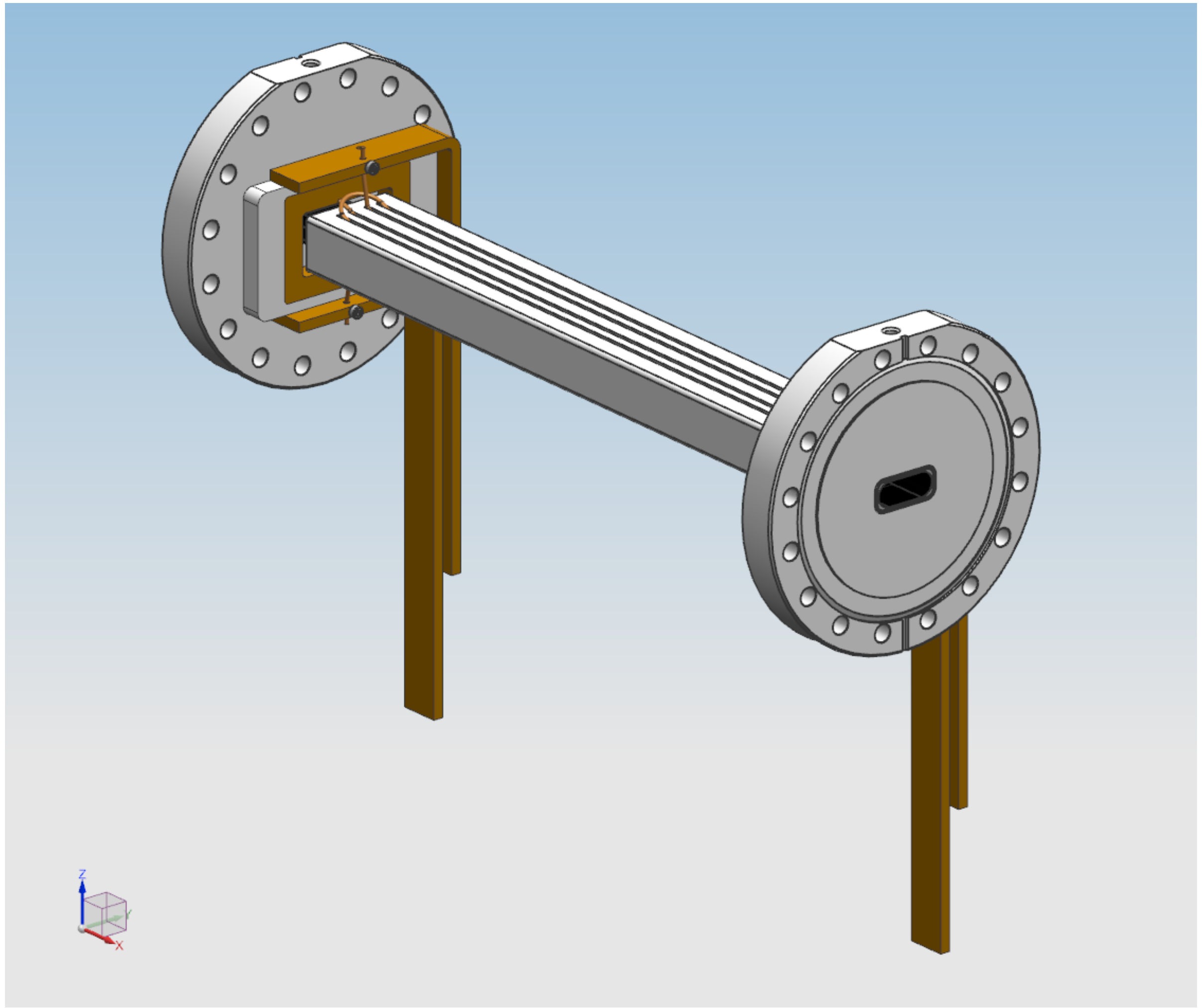
Status and Schedule





First ceramics production

Status and Schedule



Summary

- DDK allows off-axis and on-axis injection
- Transparent injection is challenging
- 2 independent power supplies
- A prototype for ALBA is ongoing

Thank you for your attention !!