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Task 7.3: VAriable Dipole for the Elettra Ring

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VAriable Dipole for the Elettra Ring - VADER

- **Task 7.3** within I.FAST **WP7**: High Brightness Accelerators for Light Sources
- Partners and collaborators:

CERN
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Elettra Sincrotrone Trieste
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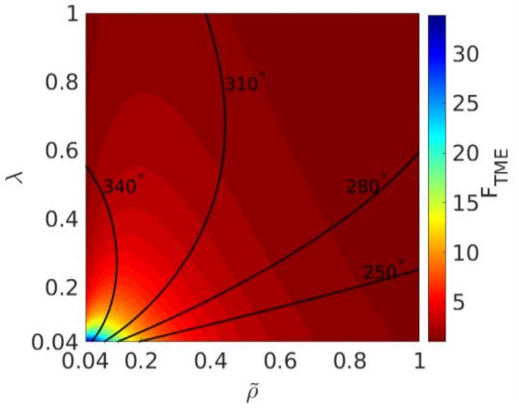
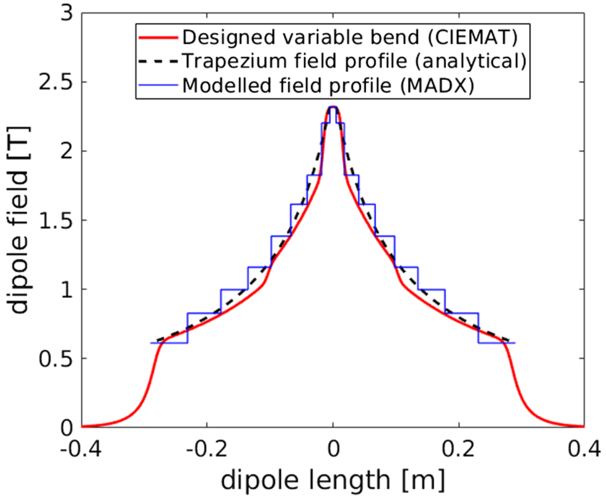
KYMA
R. Geometrante

VADER objectives

- **Fabricate** an innovative dipole magnet prototype with longitudinal varying dipole field, including a transverse gradient for the ELETTRA upgrade
- Permanent magnet **concept** with trapezoidal bending radius, **2.3 T** peak field and ~**10 T/m** gradient, already established (CERN/CIEMAT)
- Proved the **horizontal emittance reduction** to ultra-low levels of i.e. **~60 pm @ 2.86 GeV**, for the CLIC DR (M. A. Domínguez Martinez et al., IEEE Trans. Appl. Supercond. 28, 1, 2018; S. Papadopoulou et al, PRAB 22, 091601, 2019)
- First **demonstrator constructed/qualified** by CIEMAT





VADER objectives

- Keep the same **S6BA-E** lattice for Elettra and replace the LG dipoles by VADER ones.
  - Implement a **trapezoidal profile in bending radius**
  - Observe a **clear emittance reduction**

- Some **constraints**:
  - Same **geometrical layout**
  - Same **total bending angle** for each dipole
  - Same **dipole length**

- But also some freedoms:
  - We set the dipole **peak field at 2.3 T** (as for the CLIC magnet) instead of the current 1.8 T

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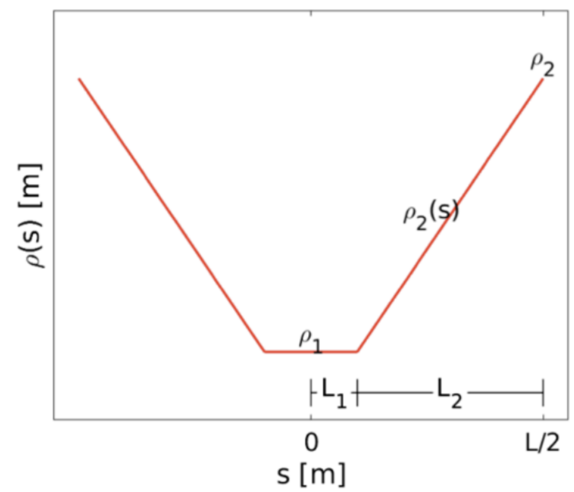
How to make a VADER?

Constrained problem. Trapezoidal profile is given by:

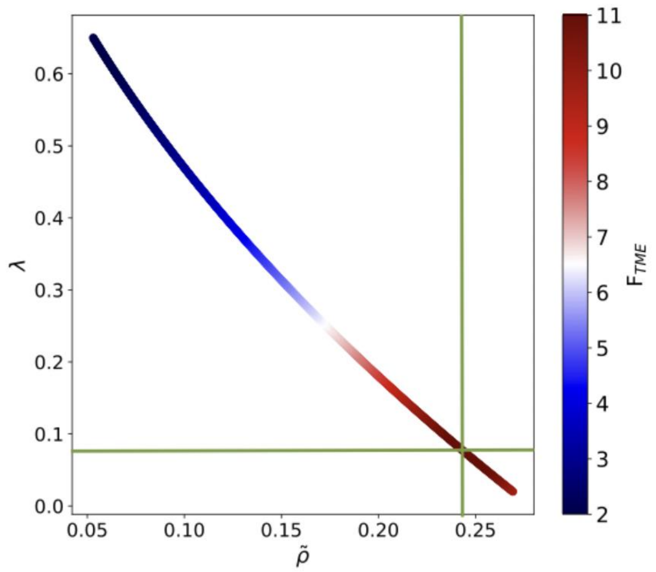
$$\rho(s) = \begin{cases} \rho_1, & 0 < s < L_1 \\ \rho_1 + \dfrac{(L_1 - s)(\rho_1 - \rho_2)}{L_2}, & L_1 < s < L_1 + L_2 = L/2 \end{cases}$$



Then, we define 2 parameters such as:

$$\lambda = \frac{L_1}{L_2} \quad \text{and} \quad \tilde{\rho} = \frac{\rho_1}{\rho_2}$$

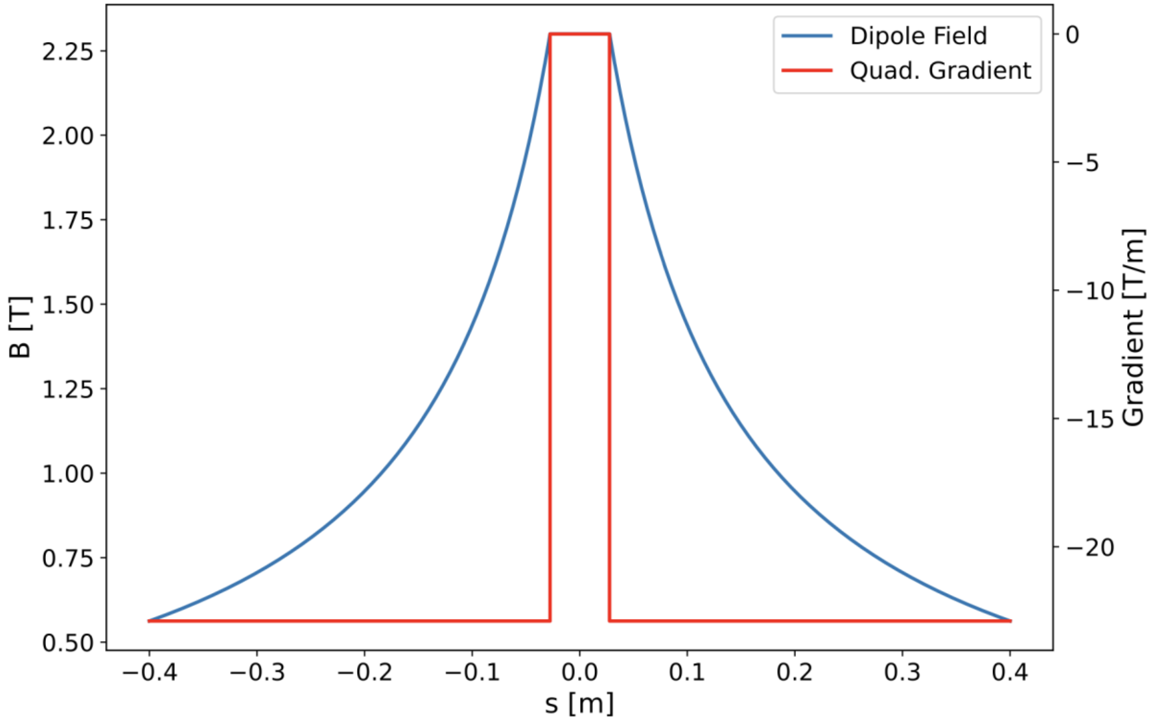
And we compute the F_{TME} as a function of those parameters:



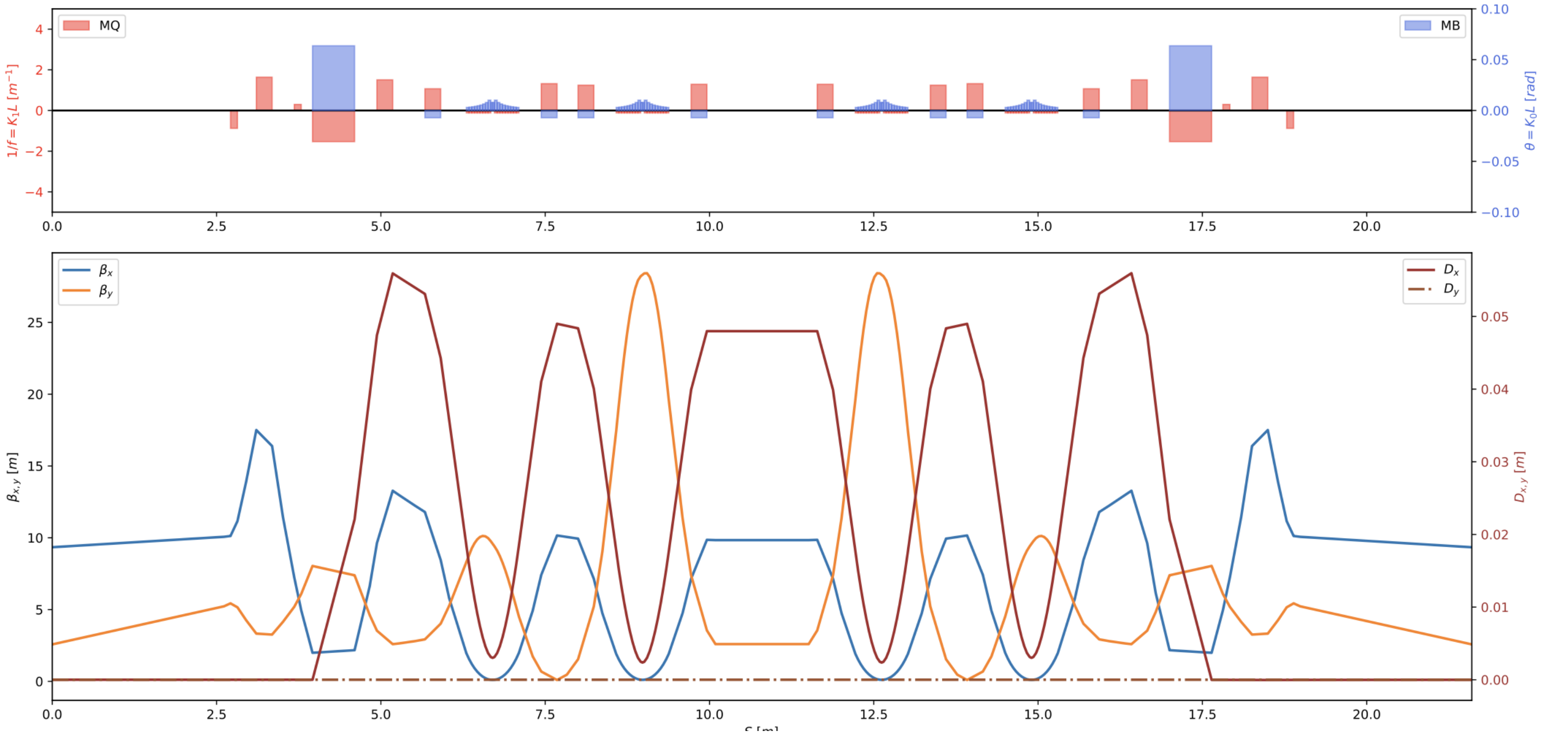
$\Rightarrow$ **Best for $\lambda = 0.074$ and $\tilde{\rho} = 0.24$.**

Profile Design and Magnet Specifications

- **Good field region:** +/- 6-8 mm
- **Gap:** 17 mm
- **Quadrupolar gradient:** 23 T/m
- Profile optimized according to the calculation of the **emittance reduction factor**
- Magnetic design on-going at CIEMAT



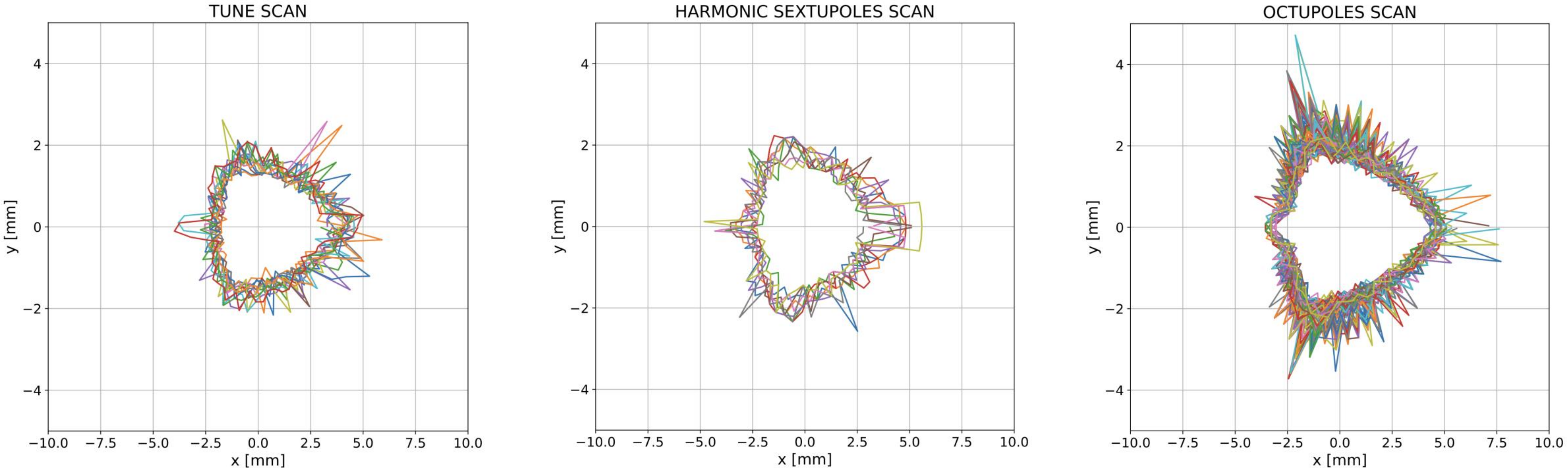
Lattice and optics design



- Optics constraints at the ID are **matched**
- **Horizontal emittance reduction from 212 to 100 pm (more than factor of 2!)**
  - ✓ Non-linear optimization on-going: **already good on-momentum DA of about 6 mm**
- **Tunes: 34.706 / 22.852**
- **Chromaticities: -157/-125**

Non-linear Optimization

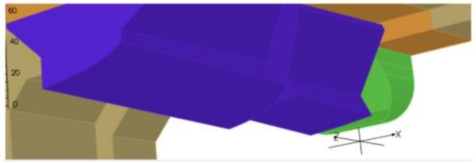
On-momentum, without error



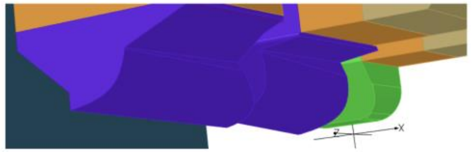
→ Up to ~ 6 mm DA in the horizontal plane, ~ 3 mm in the vertical one

VADER: Magnetic design progress

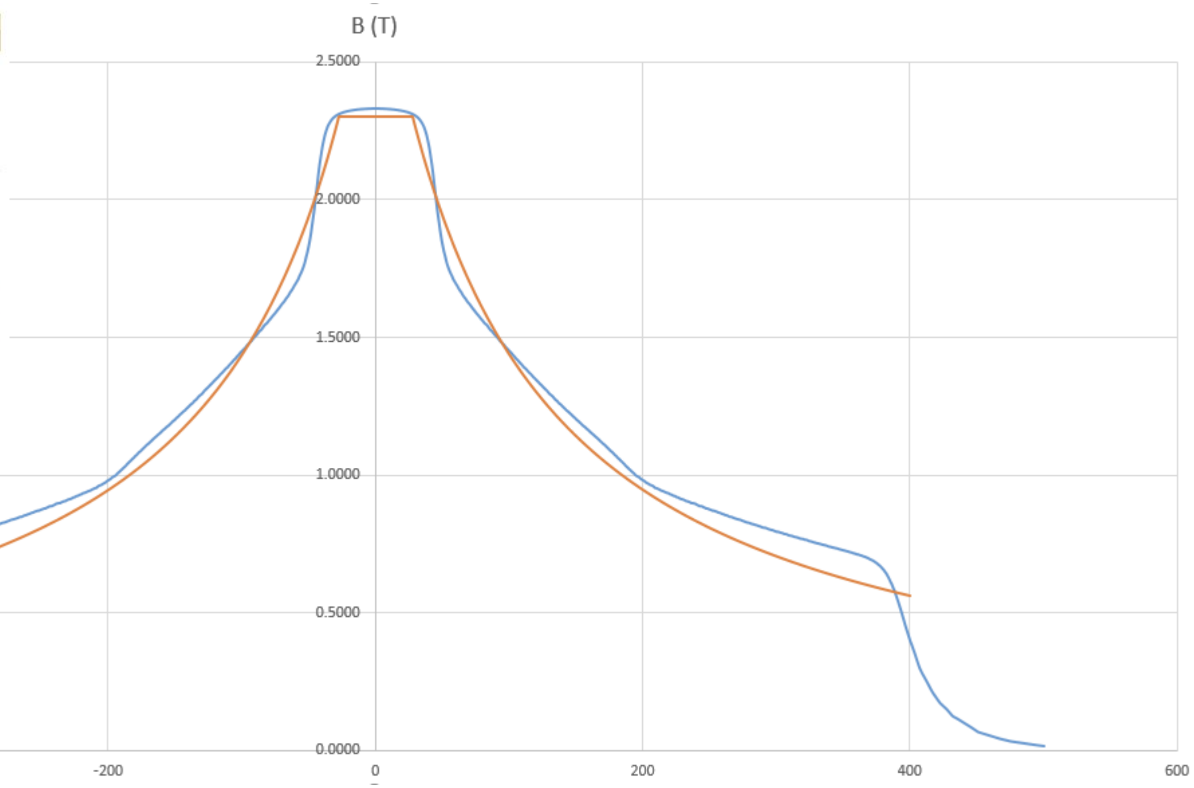
- Feasibility study with adaptation of the **CLIC demonstrator** model: close to the final phase
- Increasing **permanent magnet (NdFeB) volume** around **30%** (@ high field region), peak of **2.3T** with gap of **19mm** (17+2 mm) can be reached

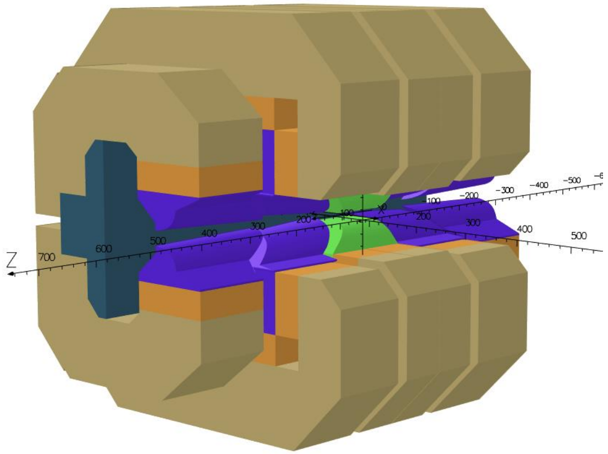


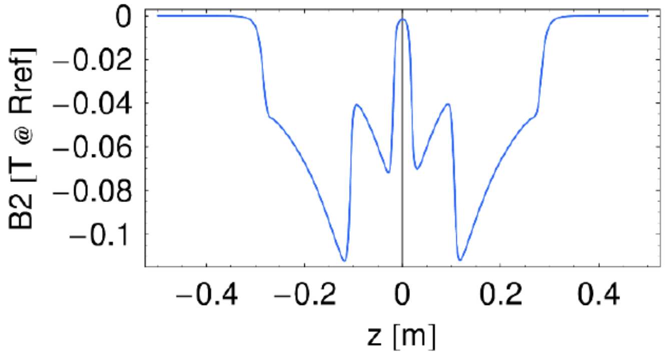
CLIC poles



VADER poles







E. Dominguez

VADER timeline

	Deliverable description	Month
1	Magnet Specifications based on optics calculations for ELETTRA	12
2	Magnetic and mechanical design (including fabrication drawings)	24
3	Fabrication of the prototype	42
4	Acceptance tests	48

Milestone **MS 26** (rows 1–2)

Deliverable **D7.3** (row 3)

Milestone **MS 27** (row 4)

- **Optics work completed** (CERN/Elettra), non-linear dynamics optimization on-going
- **Magnet specification document in final review stage**
- Internal meeting between **CIEMAT/KYMA** to **discuss fabrication process** in **fall 2022**
- **Magnetic and mechanical design** from CIEMAT **on-going** with input from KYMA for fabrication, to be **ready** by **summer 2023**
- Fabrication of the prototype by KYMA to start on **summer 2023**, ready for acceptance tests by **beginning of 2025**

Conclusions and next steps

- ✓ **Magnet profile** has been determined
- ✓ **Linear optics design** is done
- ✓ **Good emittance reduction:** factor 2 reduction compared to the Elettra 2.0 baseline
- ✓ Non-linear optimization on-going: **on-momentum DA of about 6 mm without error**
- **Good progress on magnetic design**: foreseen start of the assembly in 2024
- Milestone report in being written now
- Next step: MOGA/machine learning optimization using Python optimizers to **reach on-momentum DA without error above 7-8 mm**
- Final step: implement real profile in MAD-X and simulate the obtained emittance

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Thank you for your attention!

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