



# 3D Electromagnetic Time-Domain wake and impedance solver

---

CSC on IT services – 08 October 2024 – Lightning Talk

Elena de la Fuente<sup>1,2</sup>

Lorenzo Giacomet<sup>1</sup>, Giovanni Iadarola<sup>1</sup>, Carlo Zannini<sup>1</sup>, Manuel Cotelo<sup>2</sup>

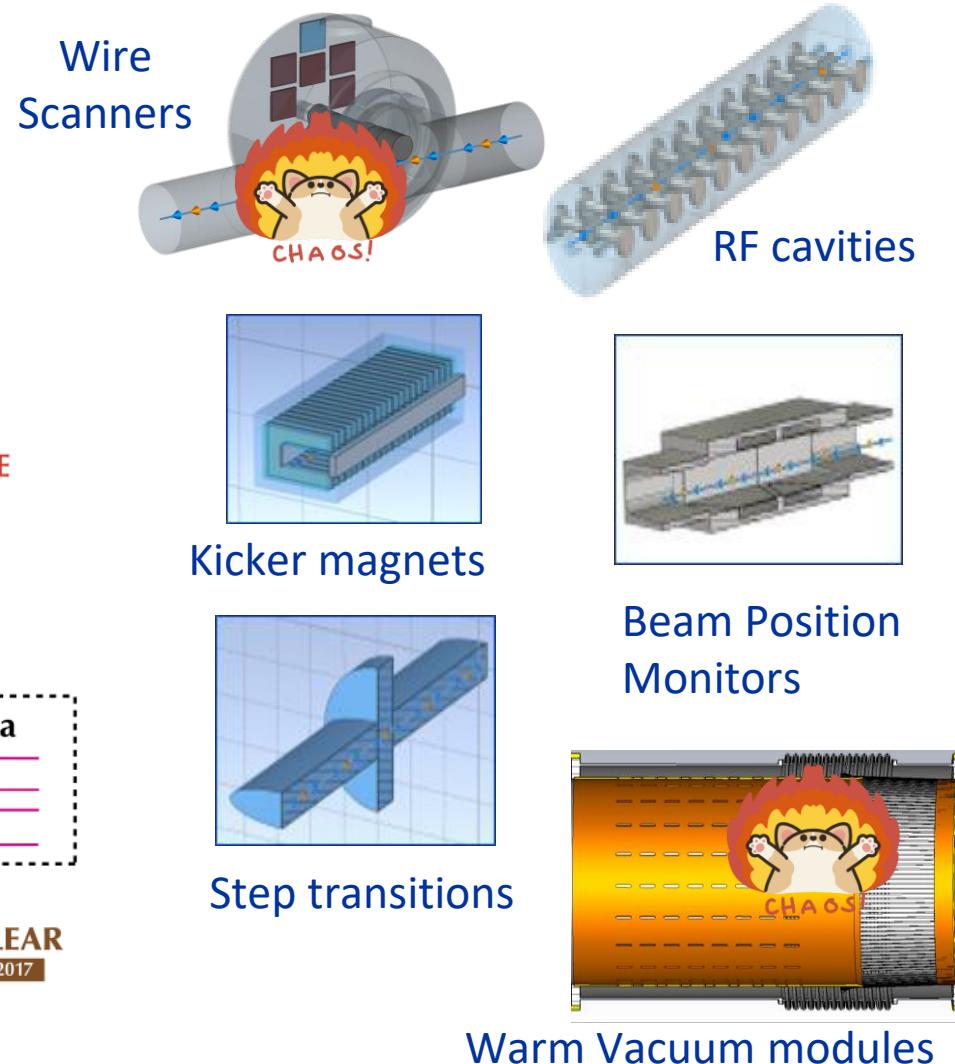
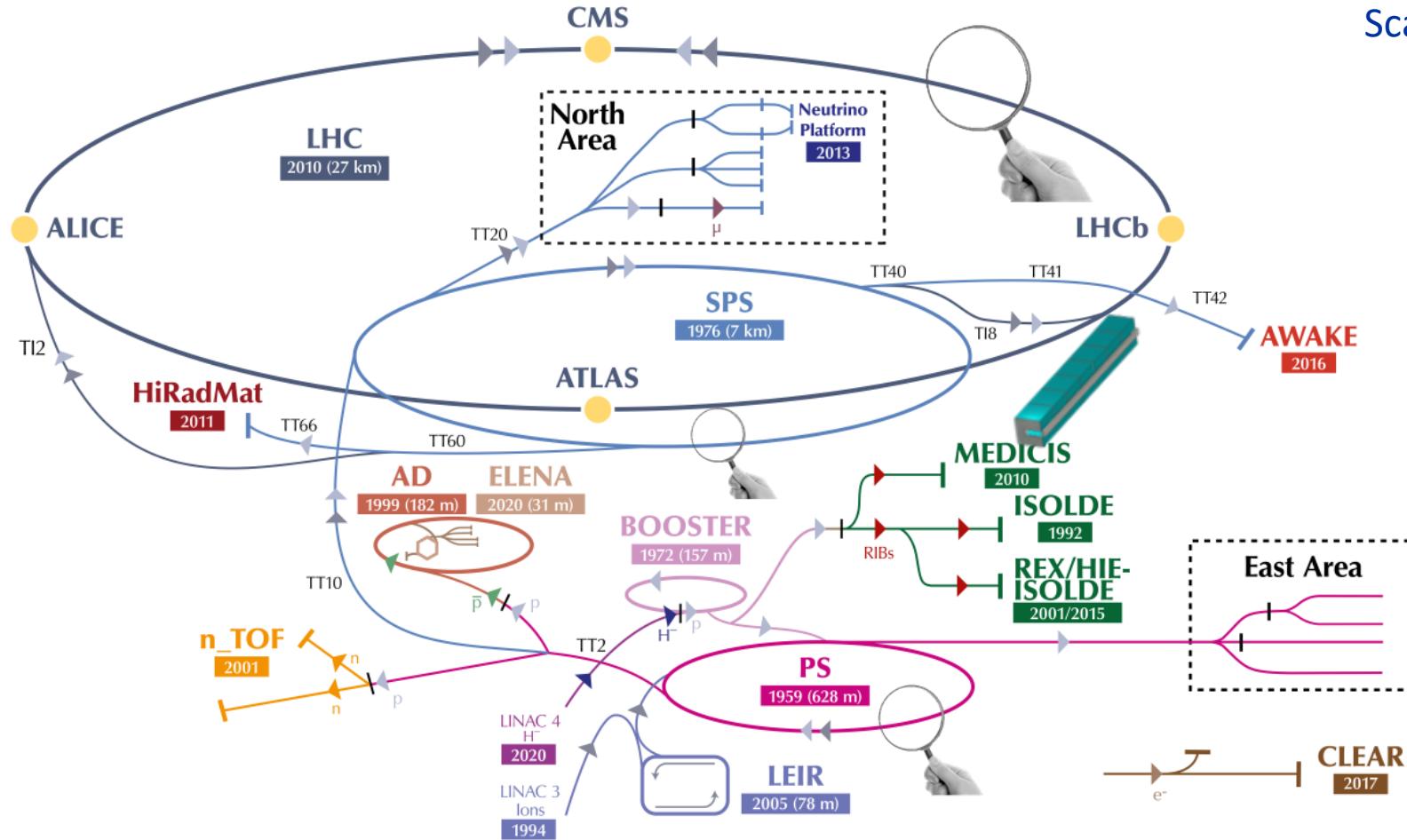
**DISCLAIMER**

Heavily simplified  
concepts !

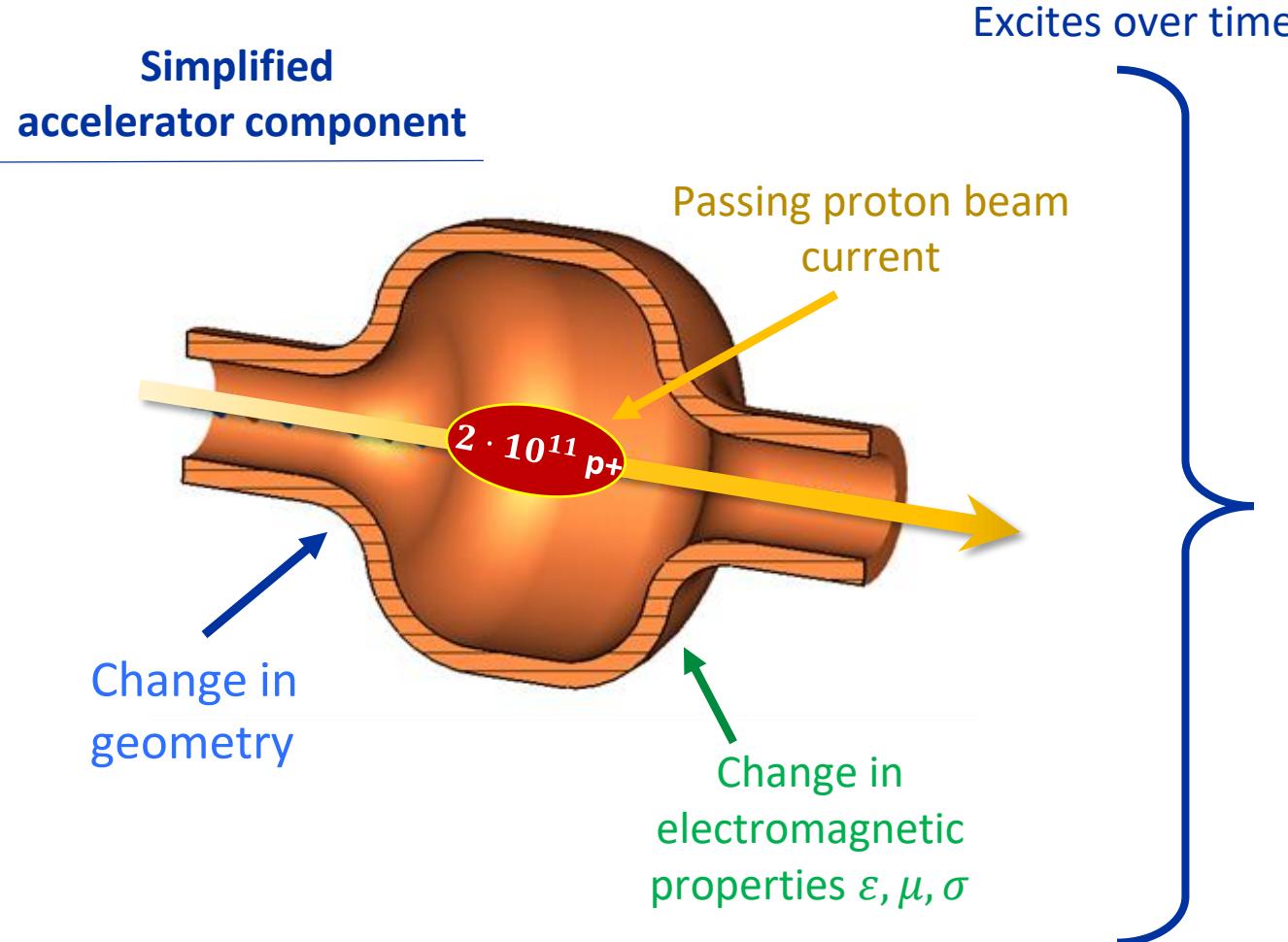
<sup>1</sup>CERN, Geneva Switzerland

<sup>2</sup>IFN-GV, Polytechnic University of Madrid, Madrid, Spain

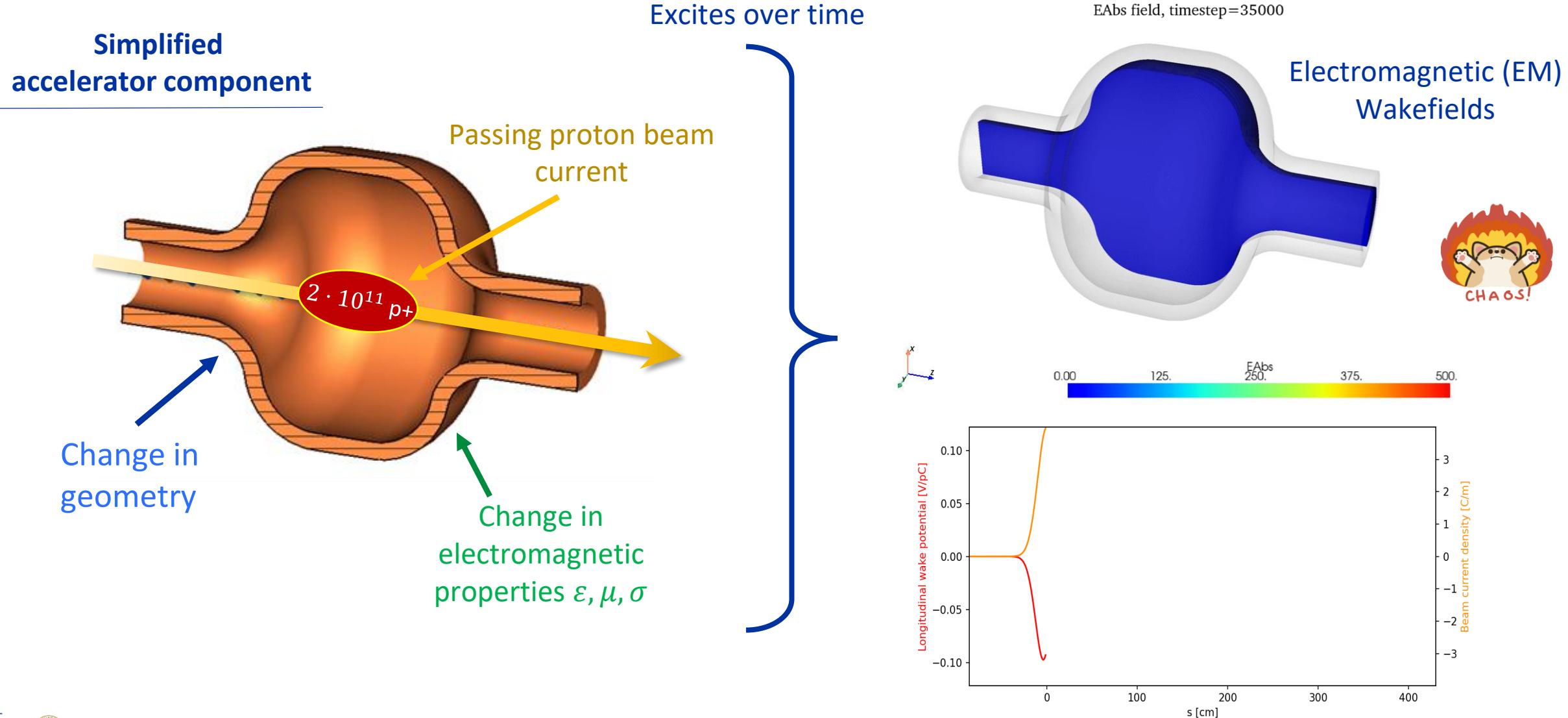
# Accelerator components... can break



# One of the causes... wakefields & impedance



# One of the causes... wakefields & impedance



# To calculate wakefields... Numerical solver

Maxwell Equations (Integral form)

$$\oint_{\partial A} \mathbf{E} \cdot d\mathbf{s} = - \iint_A \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{A}$$

$$\oint_{\partial A} \mathbf{H} \cdot d\mathbf{s} = - \iint_A \left( \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J} \right) \cdot d\mathbf{A}$$

$$\iint_{\partial V} \mathbf{B} \cdot d\mathbf{A} = 0$$

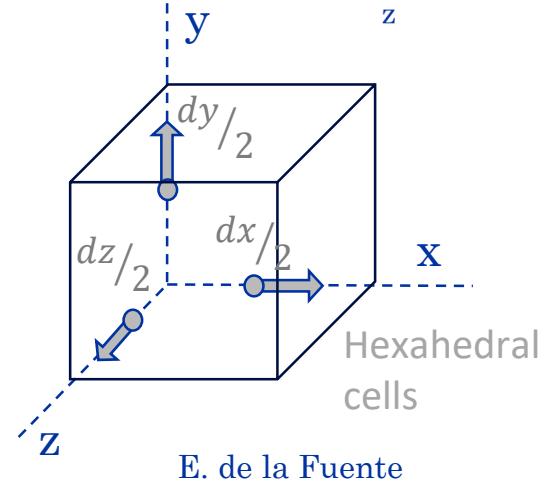
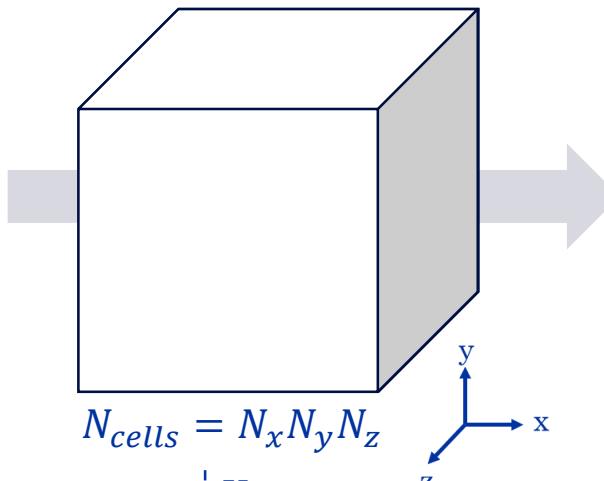
$$\iint_{\partial V} \mathbf{D} \cdot d\mathbf{A} = \iiint_V \rho dV$$

$$\mathbf{D} = \epsilon \mathbf{E}, \quad \mathbf{B} = \mu \mathbf{H}, \quad \mathbf{J} = \sigma \mathbf{E} + \rho \mathbf{v}$$



1<sup>st</sup> approximation  
Domain discretization

$$dx, dy, dz$$



Maxwell Grid Equations

$$\mathbf{C} \mathbf{D}_s \mathbf{e} = - \mathbf{D}_A \frac{\partial \mathbf{b}}{\partial t}$$

$$\tilde{\mathbf{C}} \tilde{\mathbf{D}}_s \mathbf{h} = \tilde{\mathbf{D}}_A \left( \frac{\partial \mathbf{d}}{\partial t} + \mathbf{j} \right) \quad \text{Computer friendly!}$$

$$\mathbf{S} \mathbf{D}_A \mathbf{b} = 0$$

$$\tilde{\mathbf{S}} \tilde{\mathbf{D}}_A \left( \frac{\partial \mathbf{d}}{\partial t} + \mathbf{j} \right) = 0$$

$$\mathbf{d} = \tilde{\mathbf{D}}_\epsilon \mathbf{e}, \quad \mathbf{b} = \mathbf{D}_\mu \mathbf{h}, \quad \mathbf{j} = \tilde{\mathbf{D}}_\sigma \mathbf{e} + \mathbf{j}_{src}$$

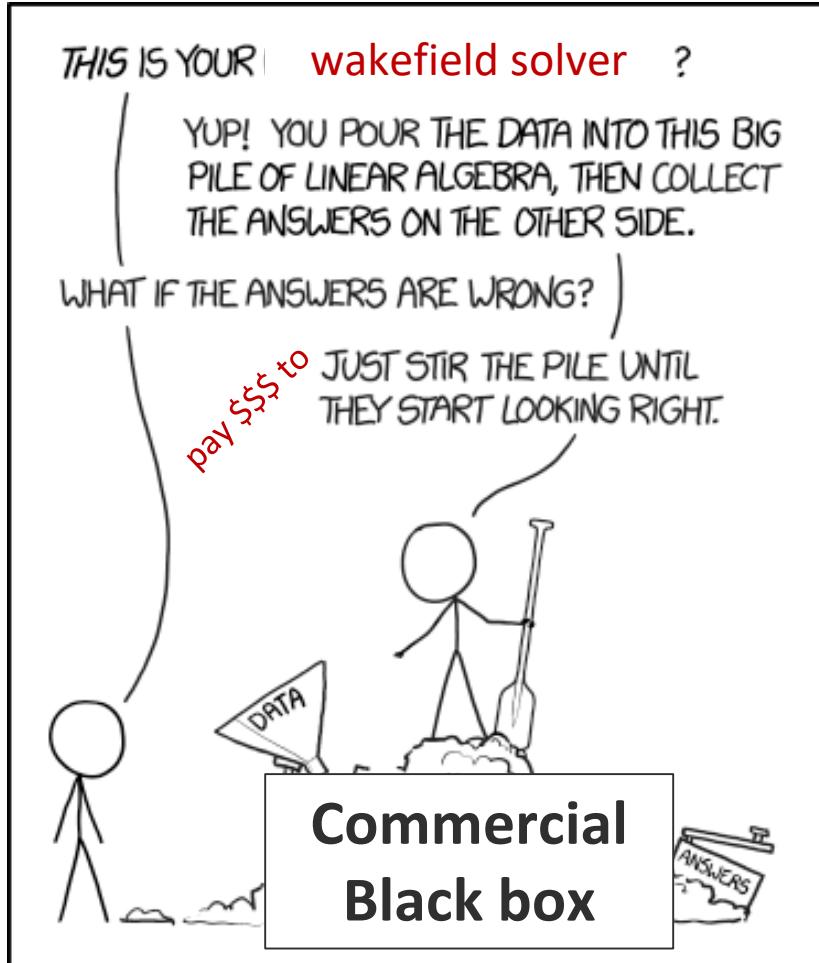


Integrals to matrices:

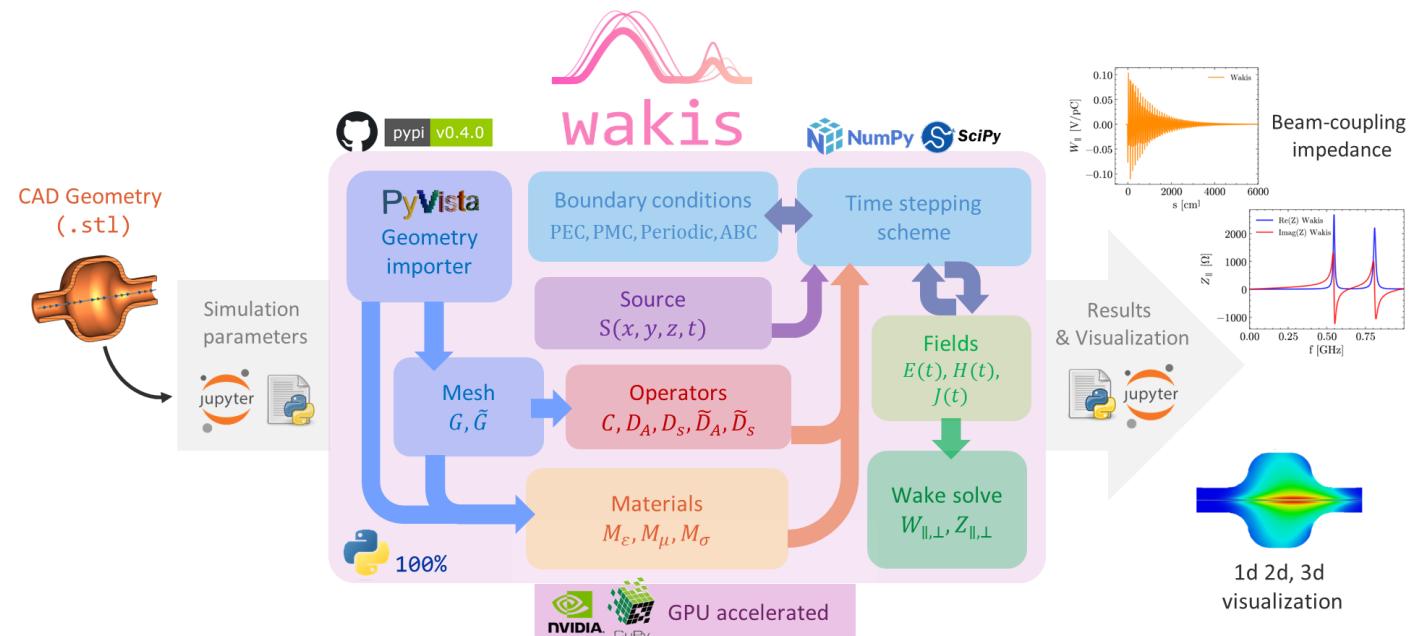
- Operators
- Grid areas and lengths
- Materials

# So far... only commercial software

<https://xkcd.com/>



My PhD project



# Open-source !

Benchmarks  
against CST studio®

Simulation examples  
⌚ ~2' to 20'

Source code

The screenshot shows the GitHub repository for `wakis`. The repository is public, has 7 branches, and 2 tags. It contains several files and folders including `benchmarks`, `docs`, `examples`, `tests`, `wakis`, `.gitattributes`, `.gitignore`, `LICENSE`, `MANIFEST.in`, `README.md`, `pyproject.toml`, `readthedocs.yml`, `release.sh`, `requirements.txt`, and `setup.py`. A recent commit by `elenafuengar` adds a 3D plot. The repository URL is <https://github.com/ImpedanCEI/wakis>. The documentation page for `wakis` is displayed, featuring a large logo, a search bar, a table of contents with sections like Overview, Installation guide, User's Guide, and API Reference, and a list of features. The documentation URL is <https://wakis.readthedocs.io/>.



# ATS sector ❤️ IT group

Improve how we write code  
& exploit IT resources



**reana**

Reproducible research data analysis platform

Flexible

Run many computational workflow engines.



Scalable

Support for remote compute clouds.



Reusable

Containerise once, reuse elsewhere. Cloud-native.



Free

Free Software. MIT licence.  
Made with ❤️ at CERN.



A bit of physics in a week of computing

CERN missions Accelerators Particle Detectors Physics Results Conclusion

**Conclusion**

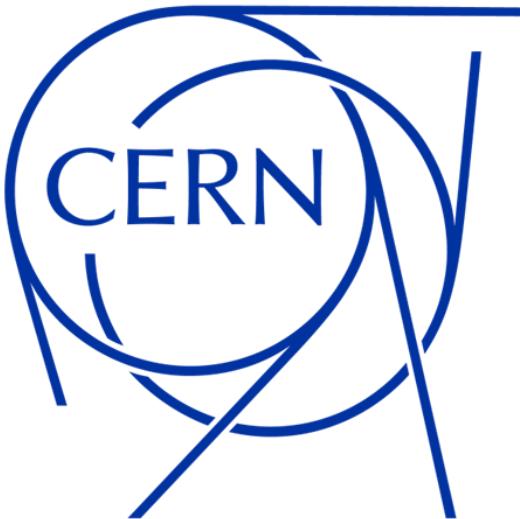
**Physics is essentially computing !**  
**And IT services are essential**

S. Ponce - CERN

inspired!



Thank you for the attention 😊



**Wakis:**  
3D Electromagnetic Time-Domain  
**wake and impedance solver**

---

Elena de la Fuente García (BE-ABP-CEI)  
[elena.de.la.fuente.garcia@cern.ch](mailto:elena.de.la.fuente.garcia@cern.ch)