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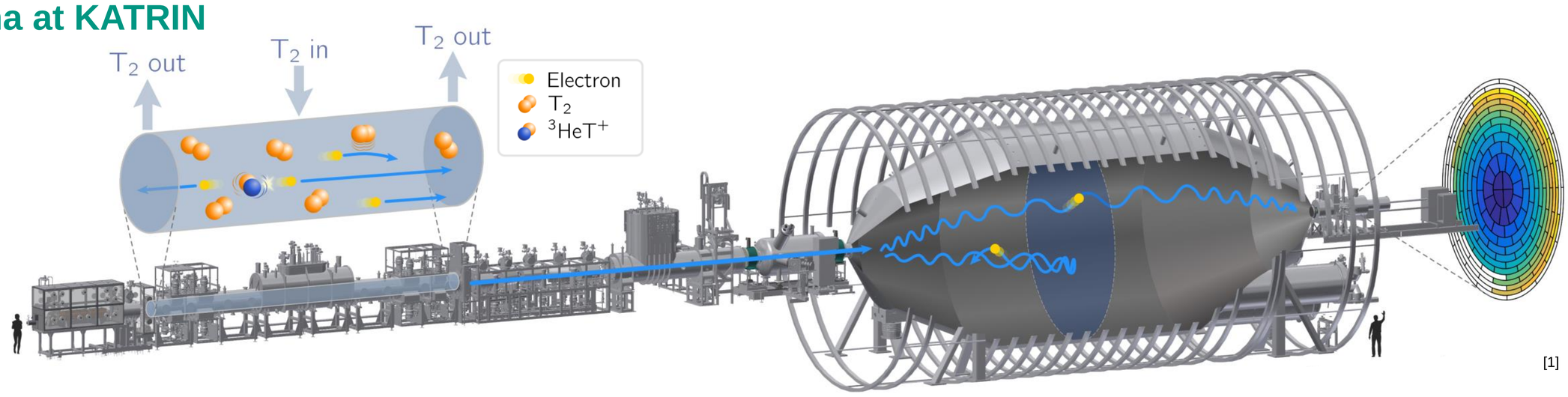
Institute for Astroparticle Physics (IAP)

Two-part simulation approach of the source plasma of the KATRIN experiment

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Plasma at KATRIN



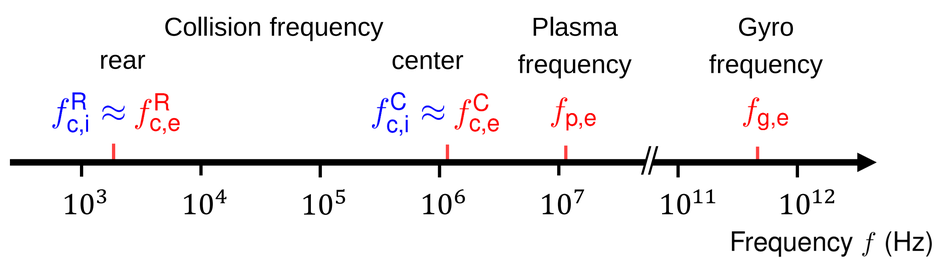
[1]

Generation
- Neutral Gas Flow with variable density
- Partial impact ionization of surrounding gas by beta electrons
- Charged density large enough for collective effects of paritcles

Relevance
- Moderates starting potential
- Influences systematically measurement through spatial and temporal inhomogeneity of potential

Properties
- Partly ionized
- Position dependent collisionality
- Low, but finite temperature
- Spectrum with thermal and non-thermal components
- Multi-species
- spatially bound

Simulation Approach

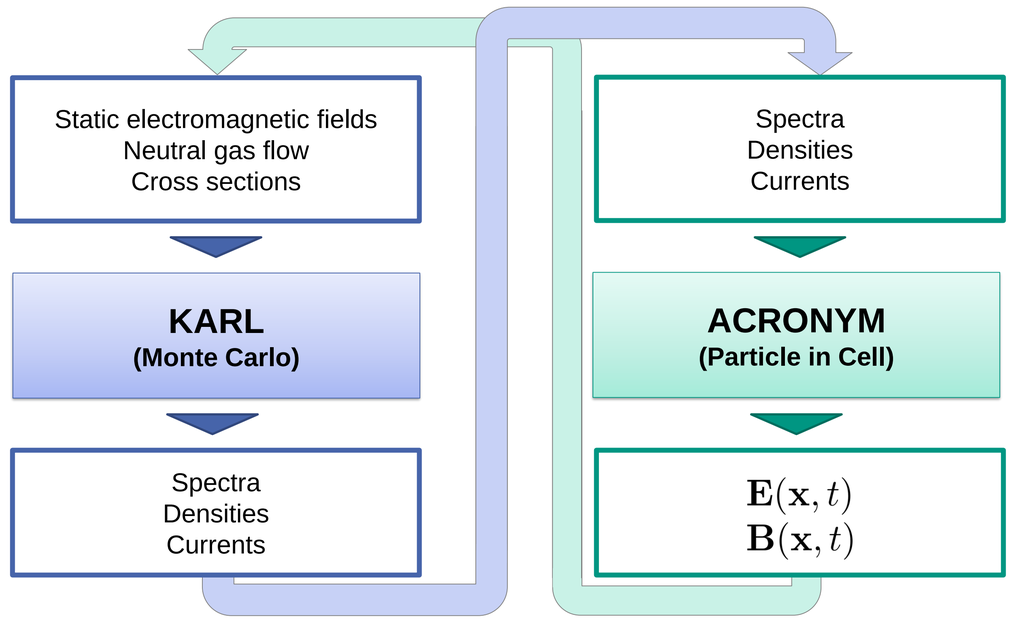


- Large difference of time scales
- Complete simulation not possible

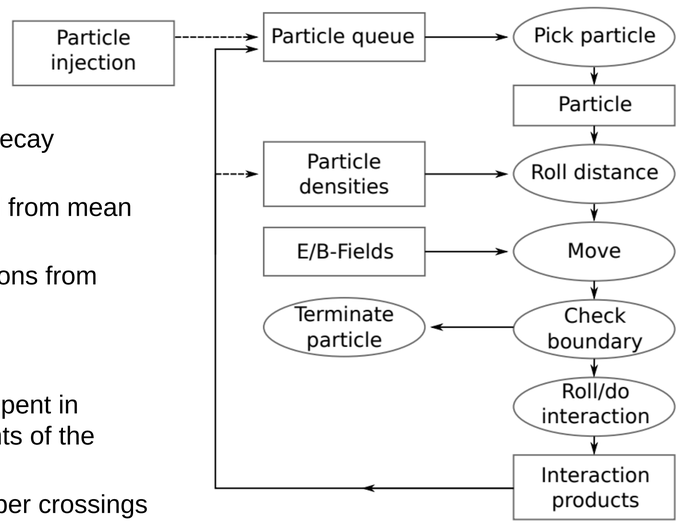
Iteration between simulation of **collisions** and **plasma**physics

Collisions through **Monte Carlo** simulation

Plasma through **Particle in Cell** simulation

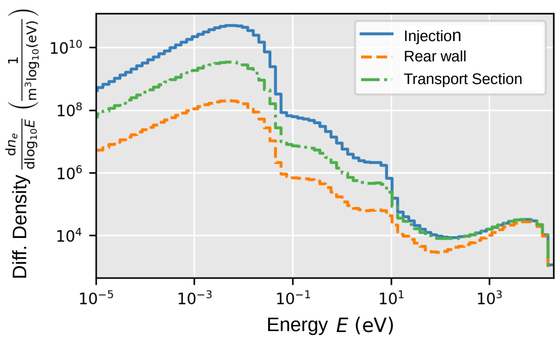


KARL



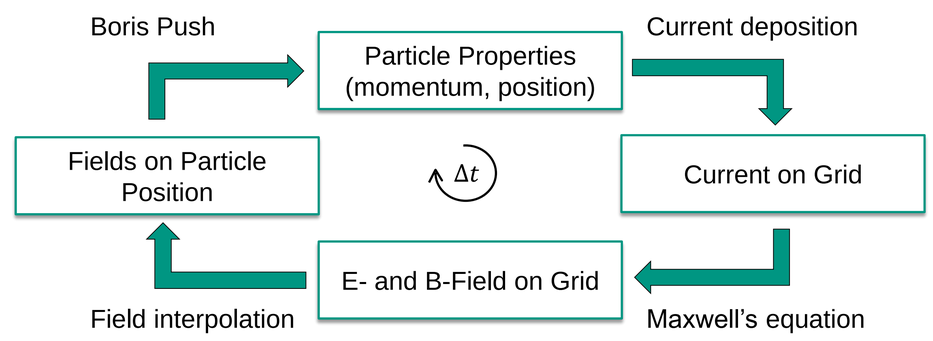
Algorithm:
- Injection from known beta decay spectrum
- Moved distance determined from mean free path
- Interactions and cross sections from literature values

Output:
- Particle density from time spent in predefined volume segments of the source
- Particle currents from number crossings through virtual barriers

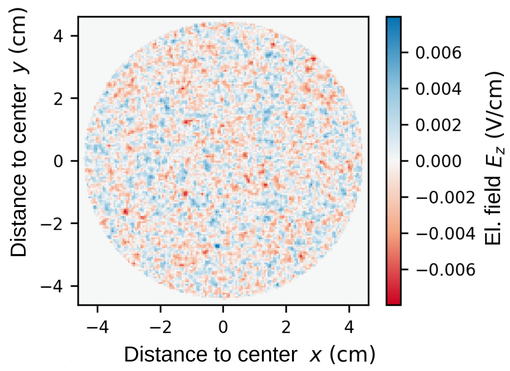


First Iteration
(Without electric field)
- Spectrum strongly dependent on position
- Trisection of spectrum with non-negligible non-thermal part ($E > 0.1$ eV)
- More precise results in tandem with ACRONYM

ACRONYM



- Fully kinetic electromagnetic solver with relativity corrections for astrophysical use
- Customized for KATRIN conditions
- $\Delta t \approx 10^{-13}$s (given by electron density)
- 10^5 timesteps to resolve plasma frequency



First Iteration
(Initial spectrum from first KARL simulation)
- Spatial and temporal fluctuations of the electric field
- No significant plasma potential differences, but now accessible by simulation
- More precise results in tandem with KARL

[1] Figure adapted from: D. Parno, K. Valerius, "Probing the neutrino mass scale with the KATRIN experiment", Europhysics News, Vol. 53, 2022

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