DTU

Measuring Ion Dynamics in the Core of European DEMO: A Design Space Exploration for Collective Thomson Scattering

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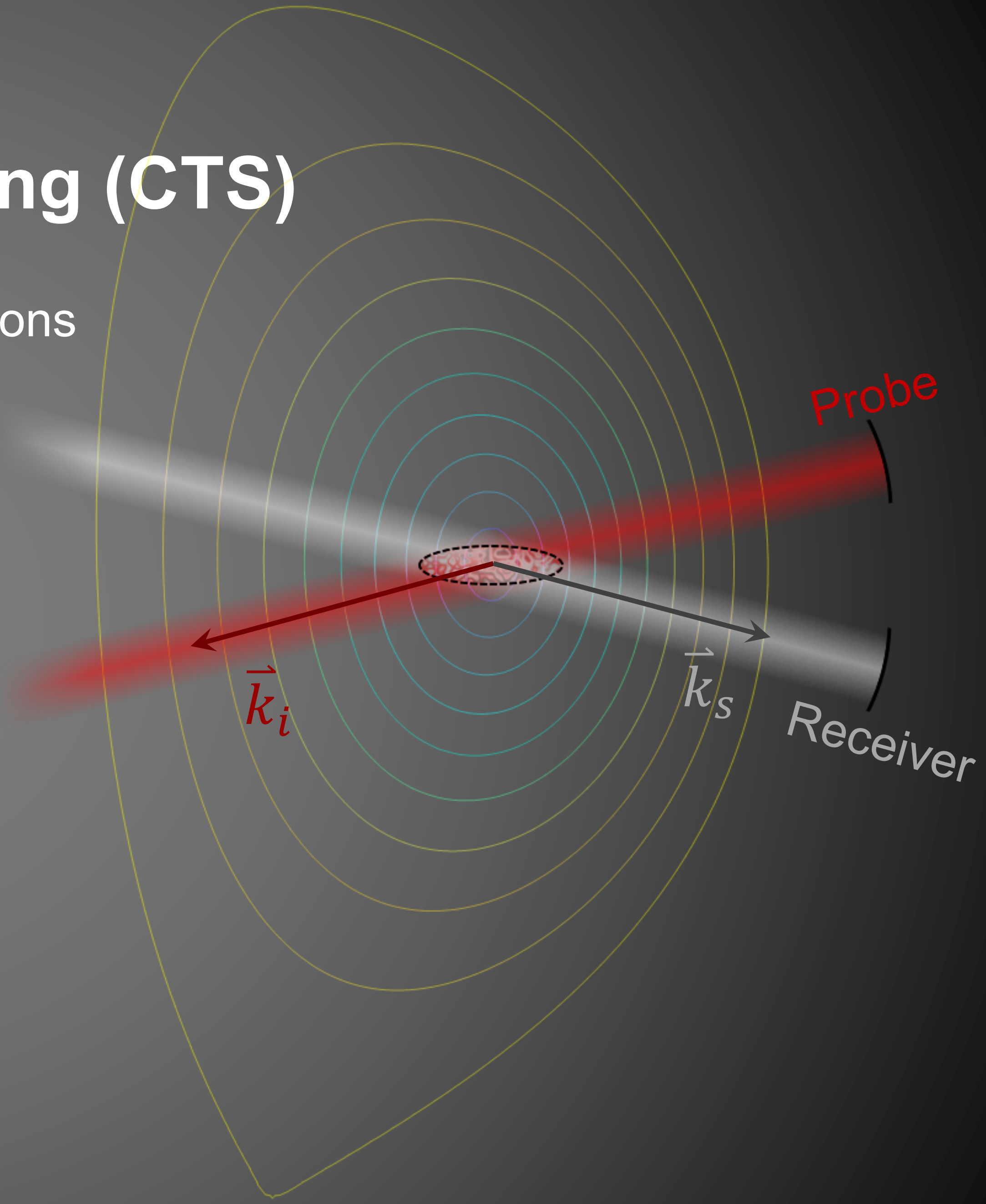
Collective Thomson Scattering (CTS)

- Probe radiation scatters off electron fluctuations
- Collective effects for $\alpha_S \coloneqq \frac{1}{|\vec{k}_s - \vec{k}_i| \lambda_D} \gg 1$

  ↪ ion properties define scattered spectrum



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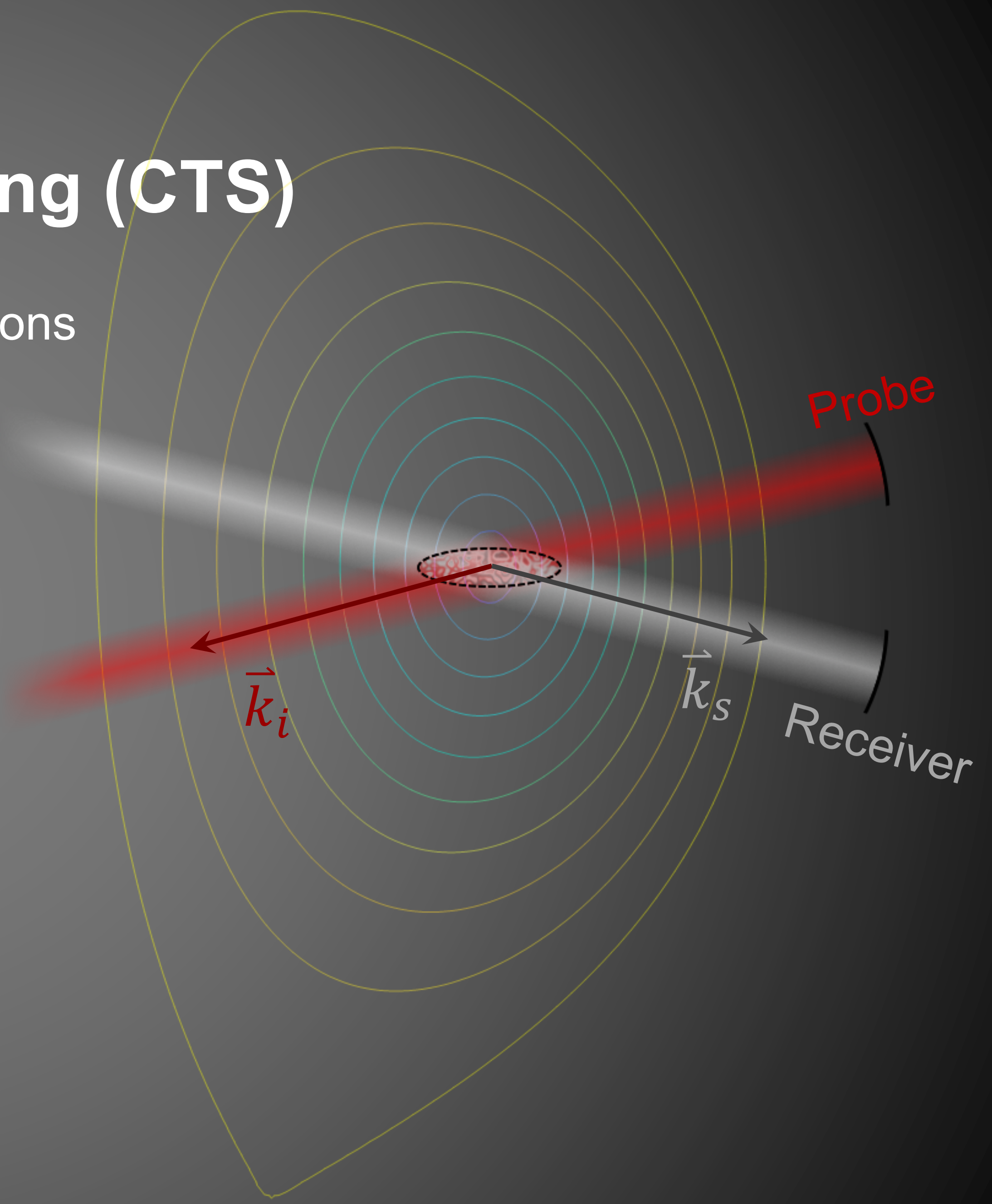
  – (projected) bulk velocity
  – relative ion abundance
  – fast ion velocity distribution
- Local measurement



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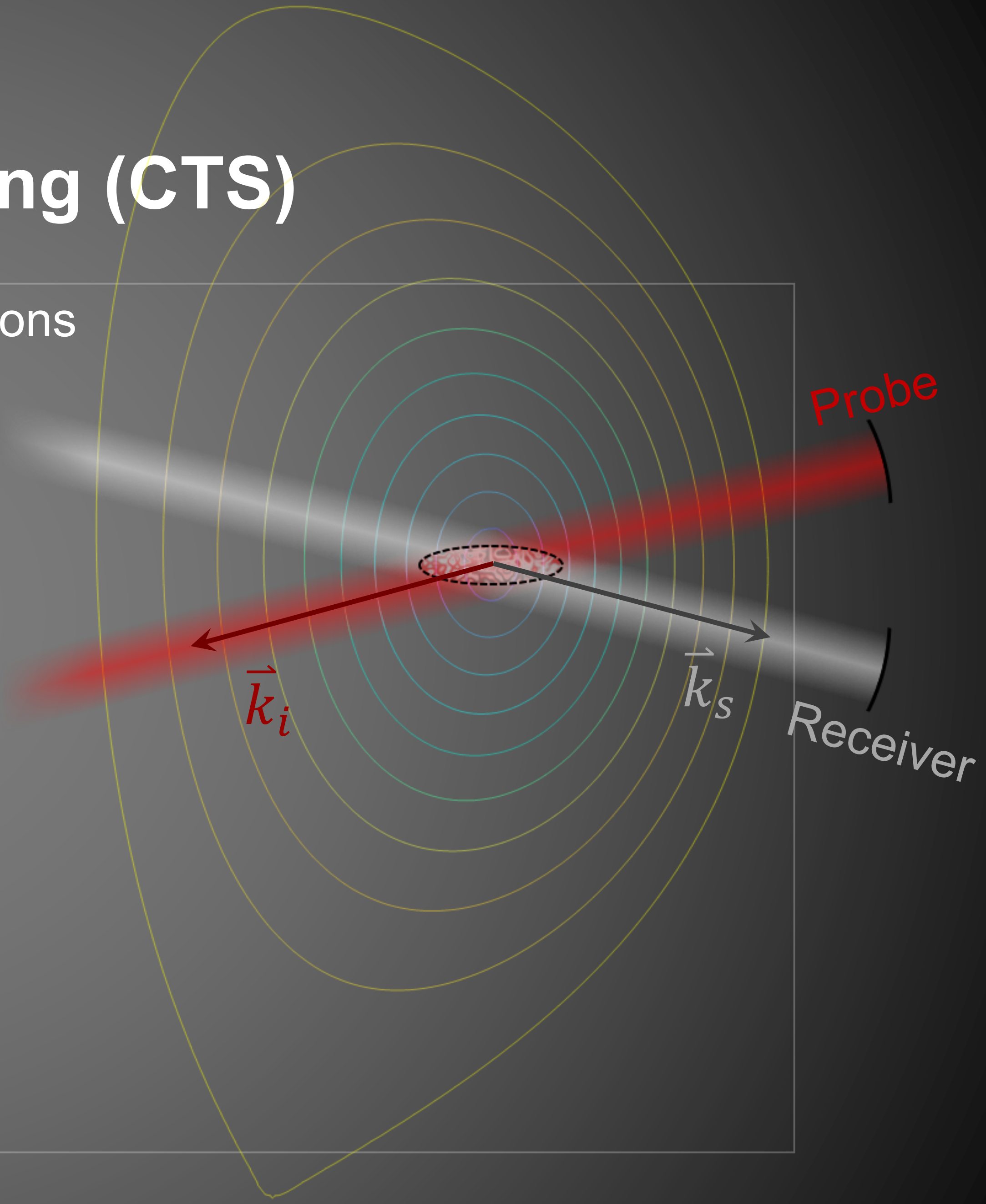
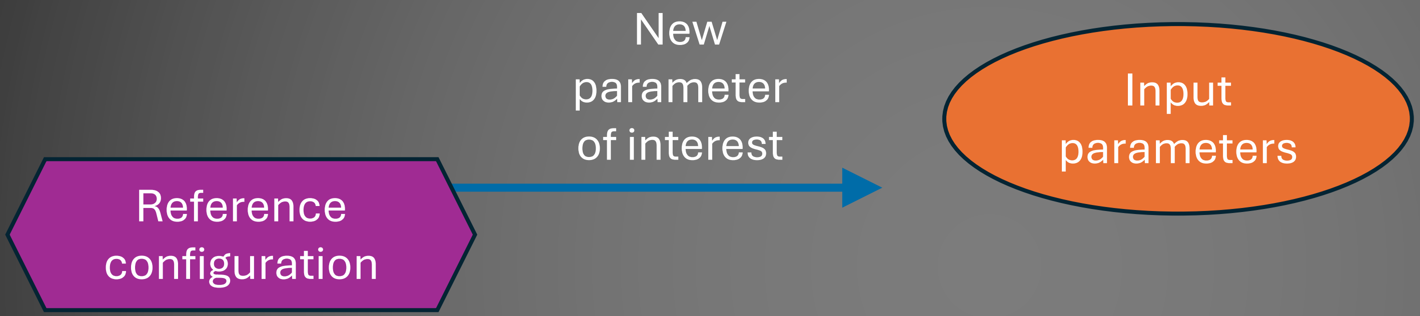


Optimisation framework

Reference configuration

Optimisation framework



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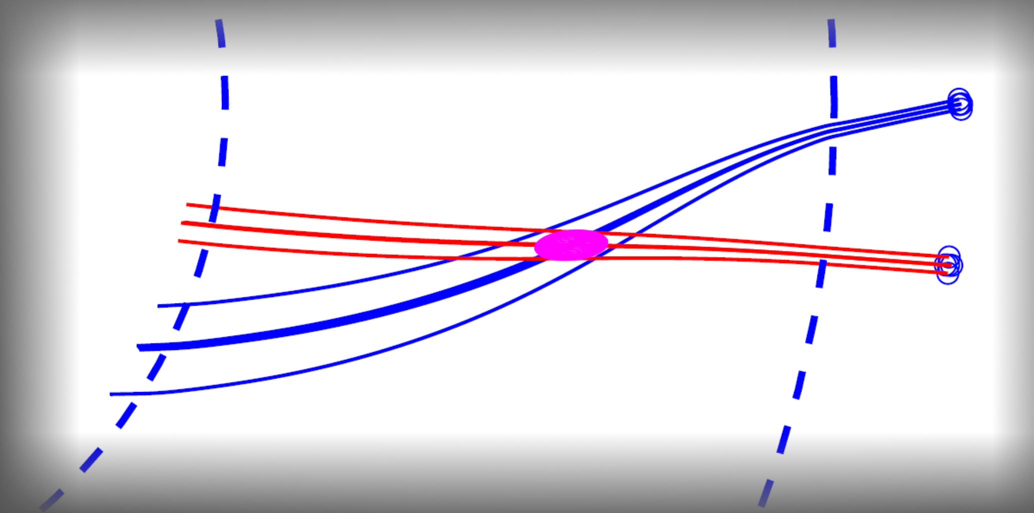
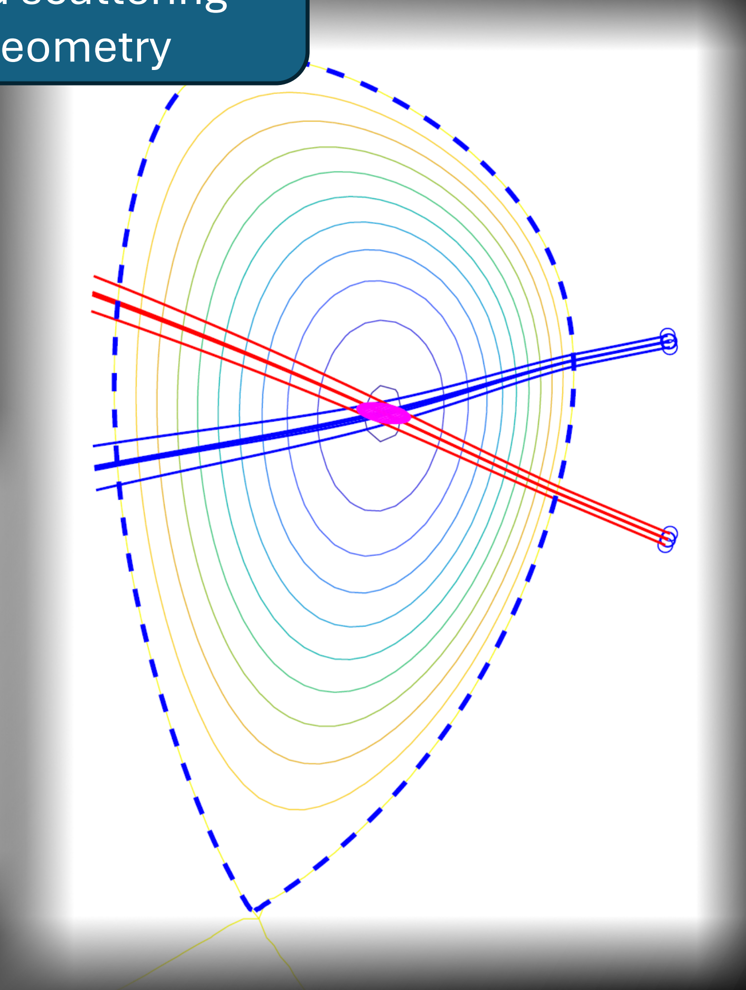
New parameter of interest

Input parameters

Ray tracing: Find scattering geometry





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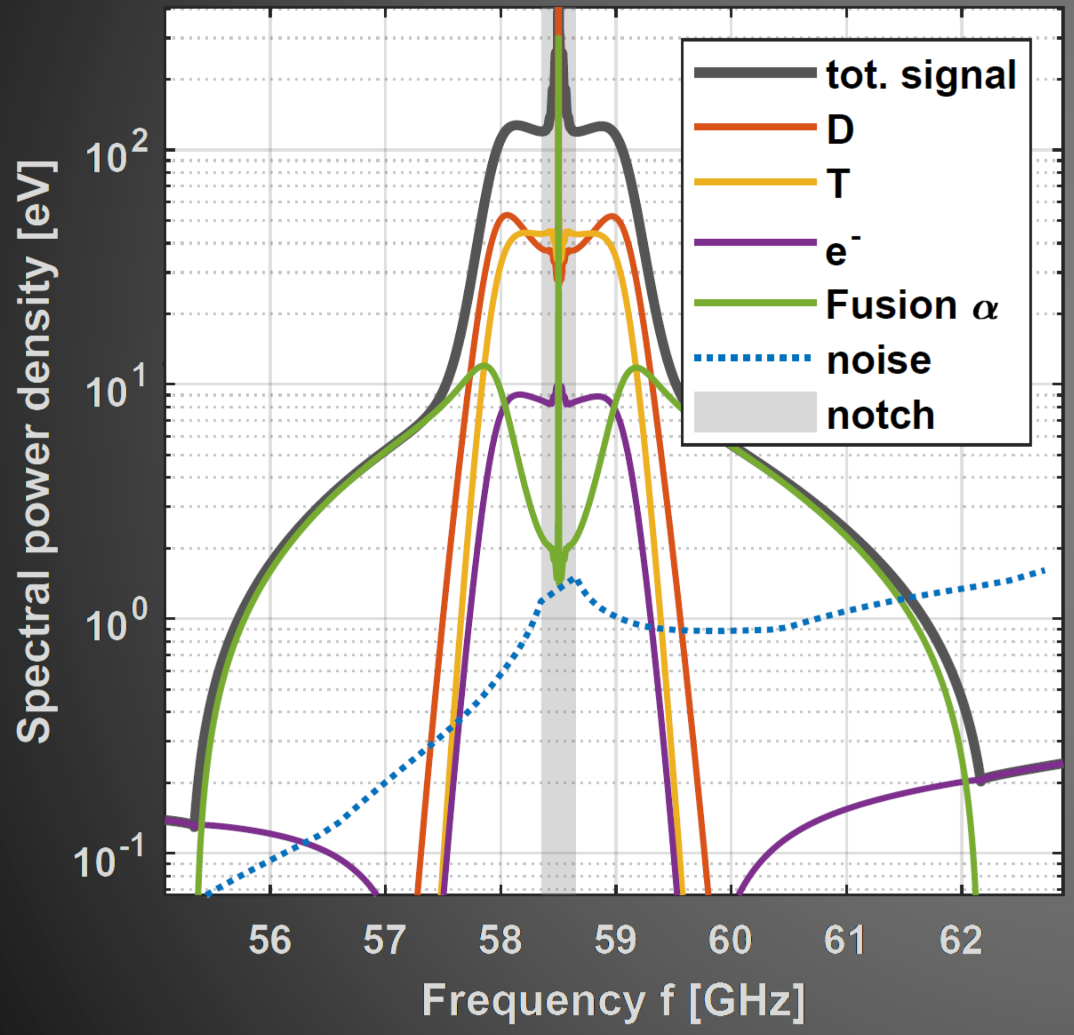

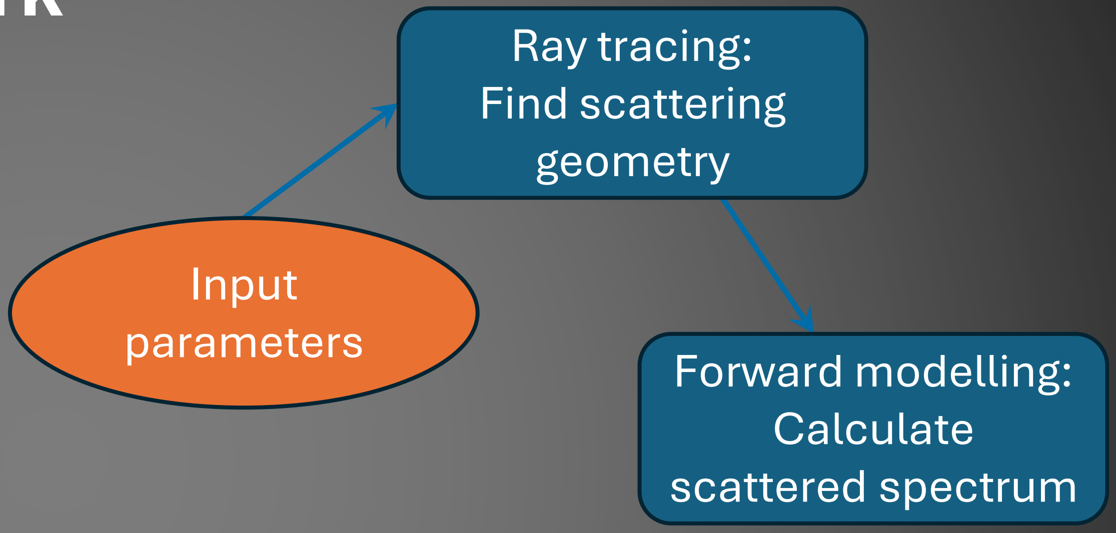

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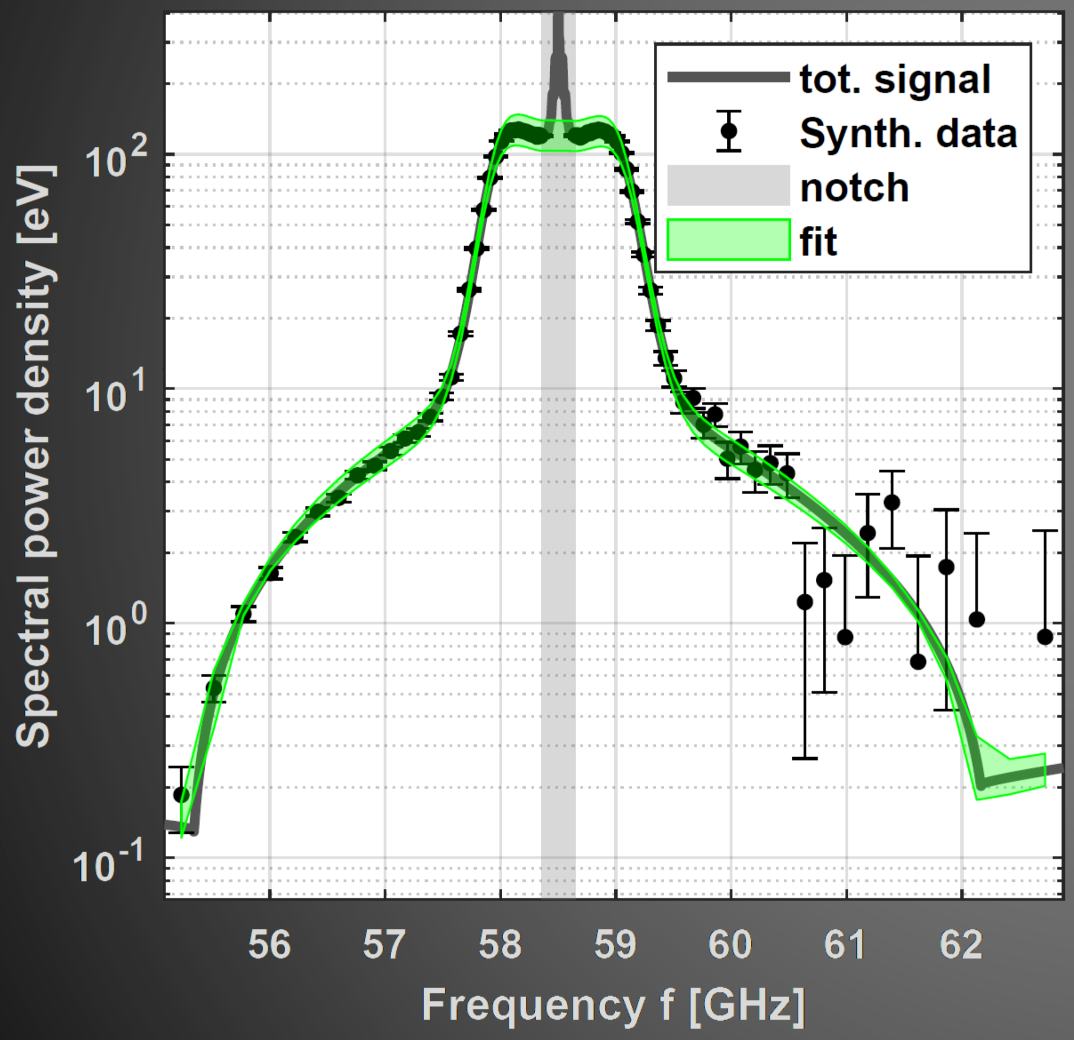

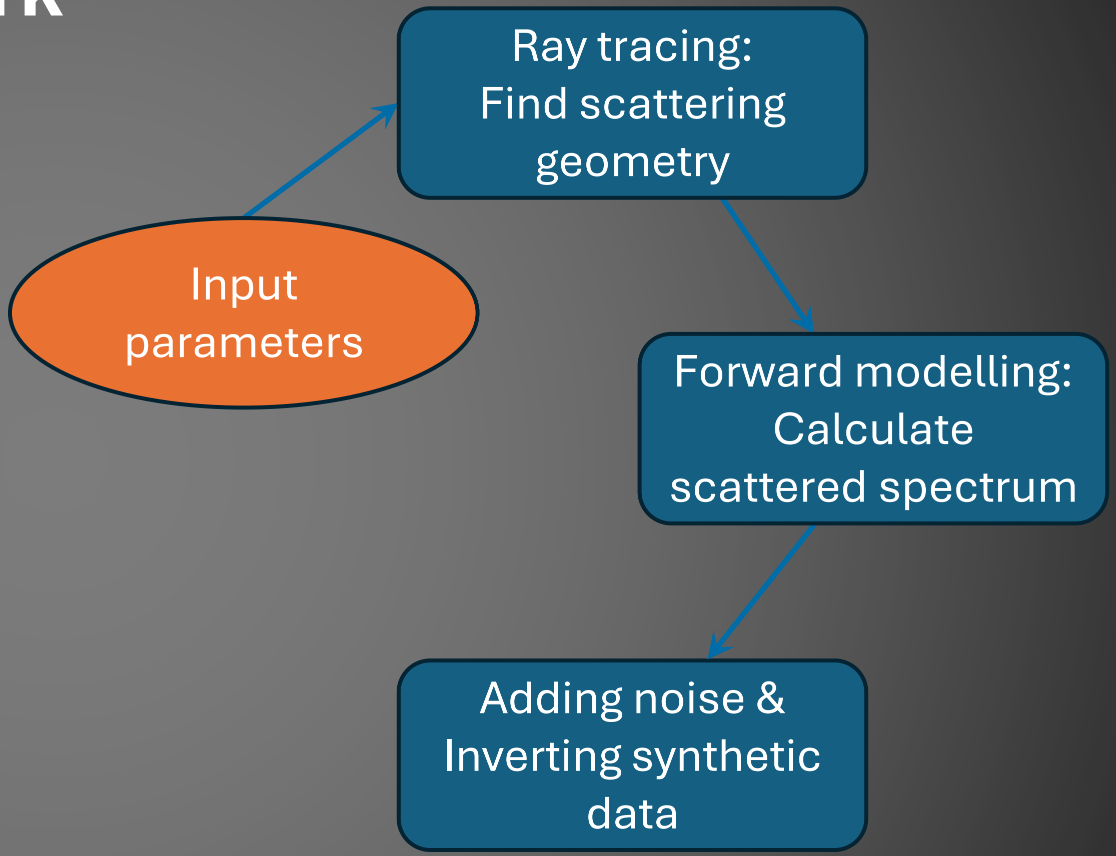

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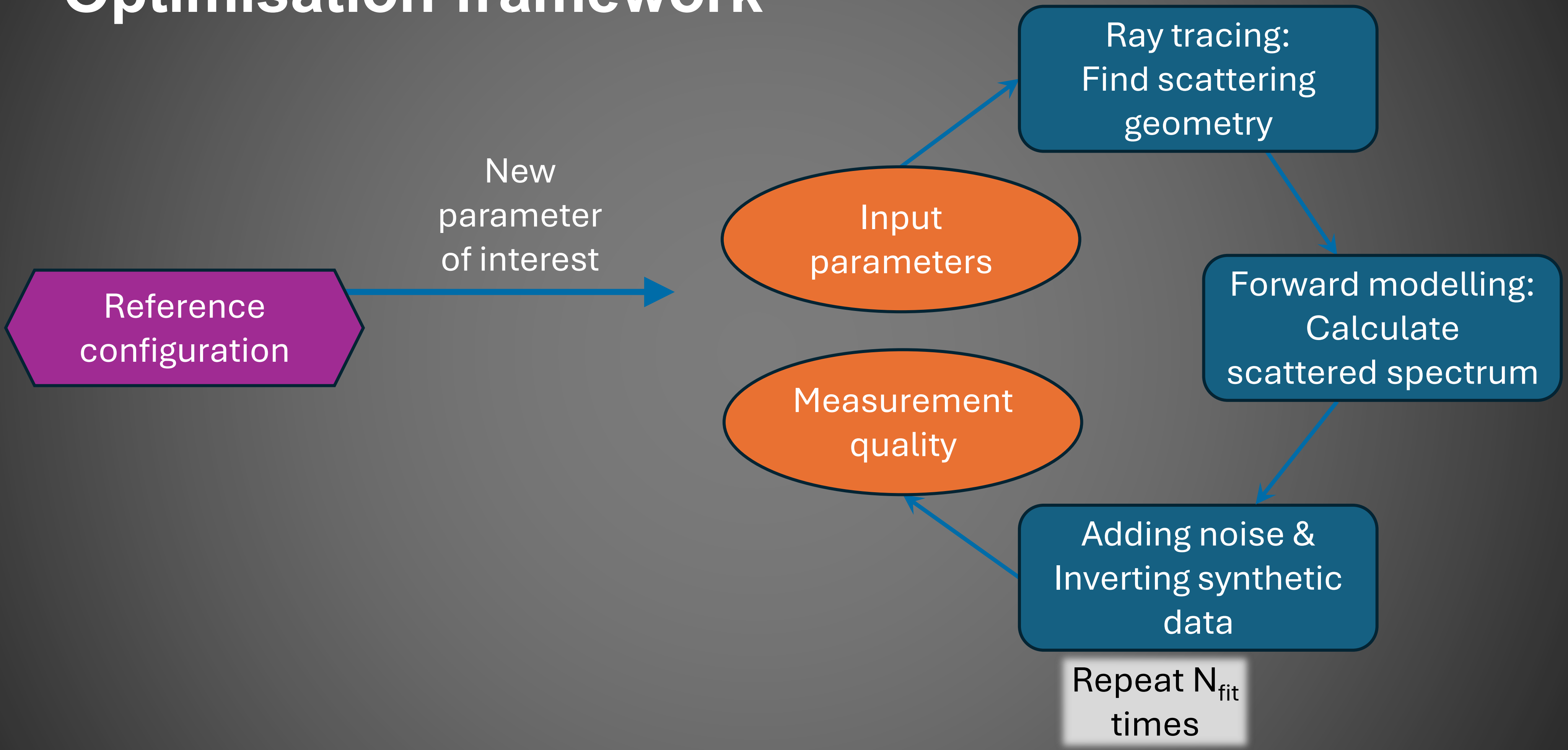

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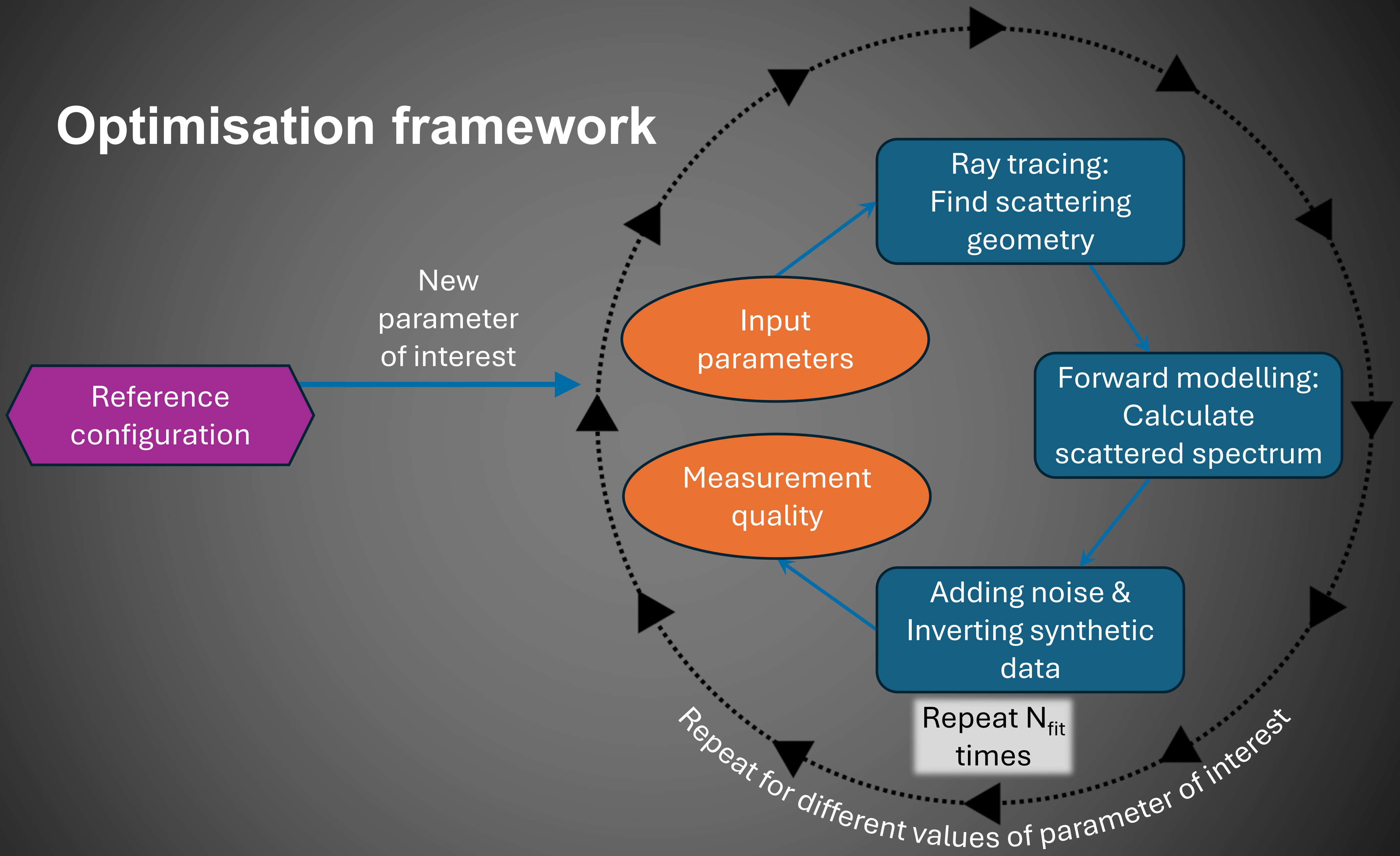

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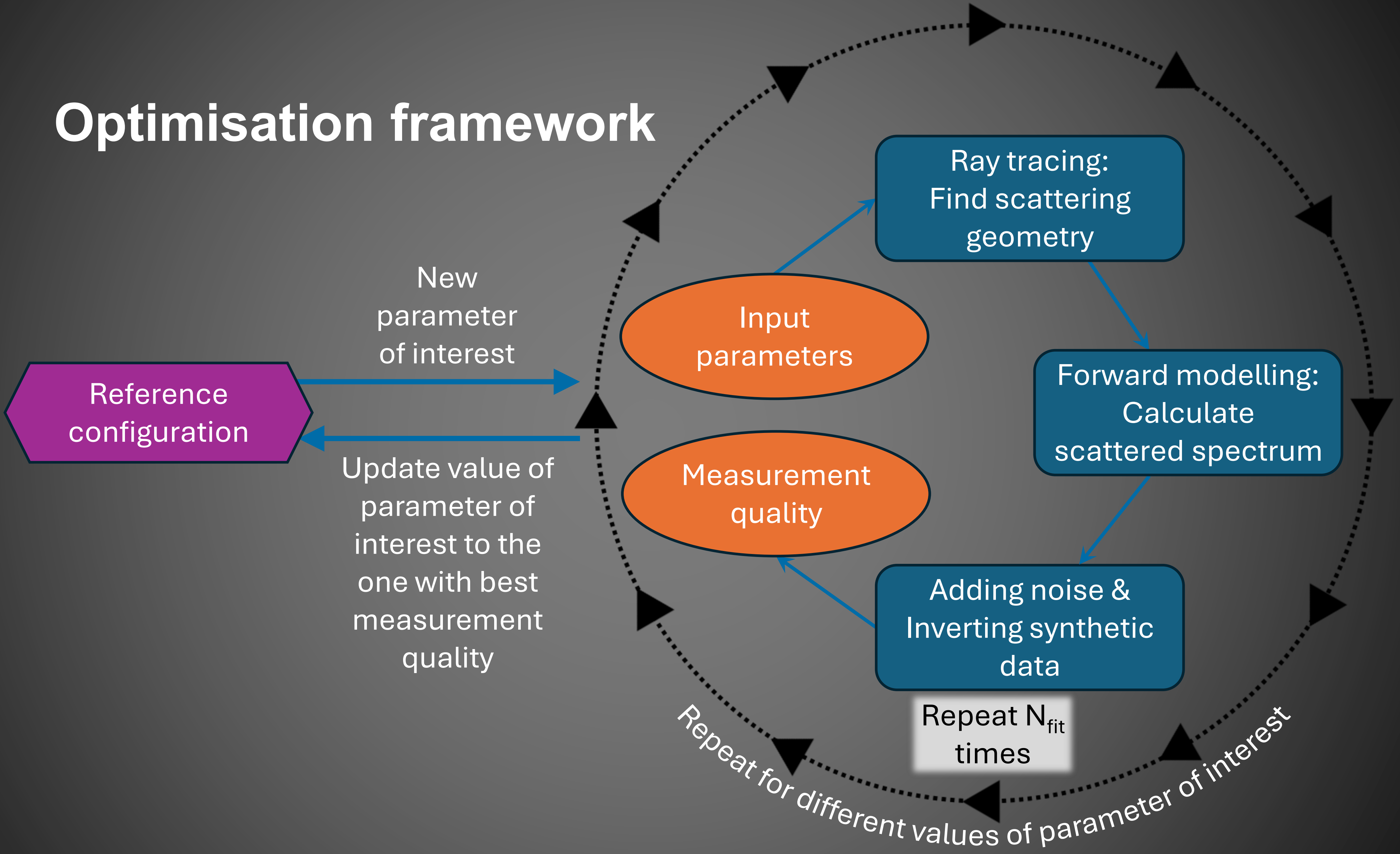
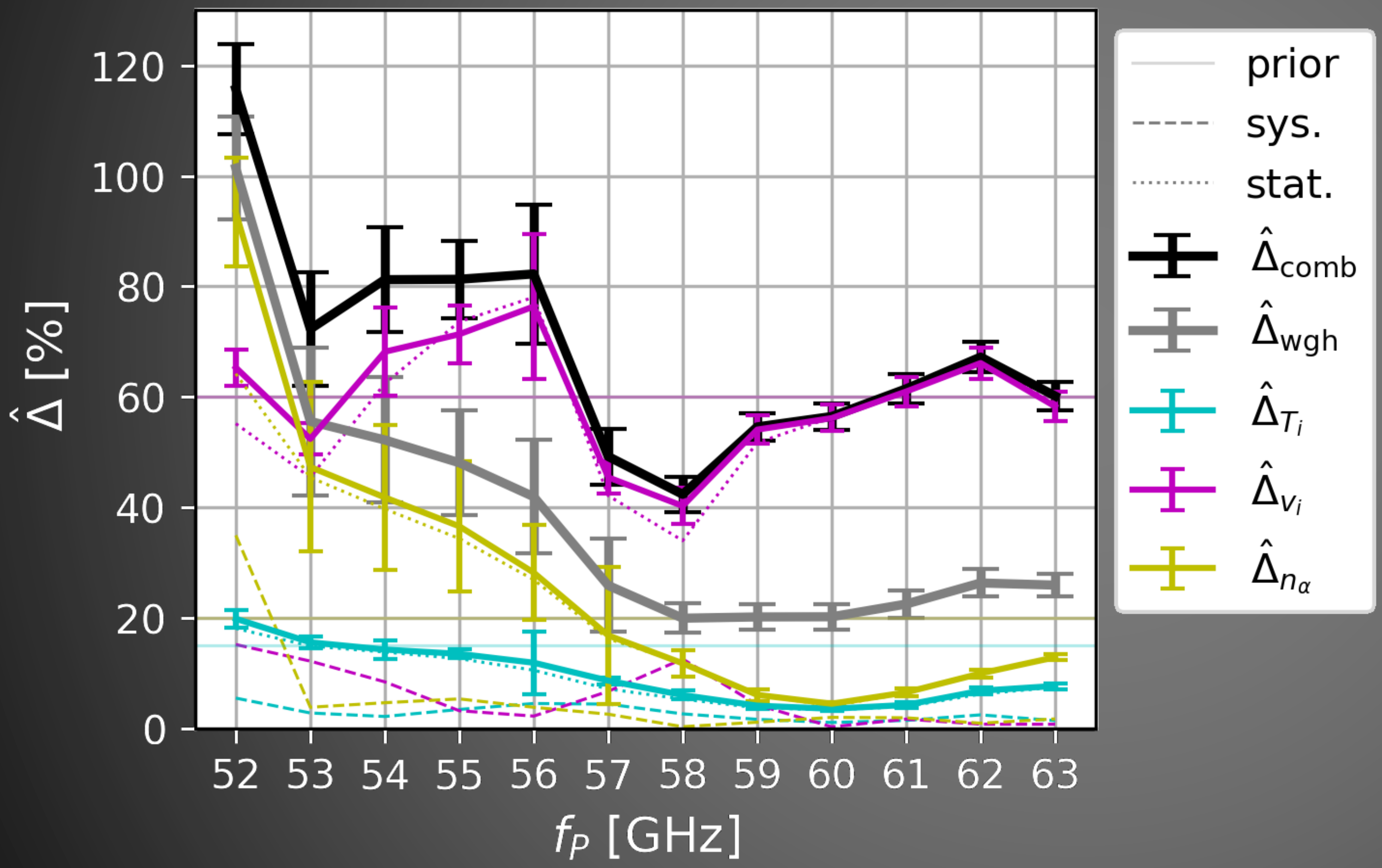


Preliminary results



Relative measurement errors $\widehat{\Delta}_X$ weighted by prior uncertainties to get $\widehat{\Delta}_{\mathrm{wgh}}$

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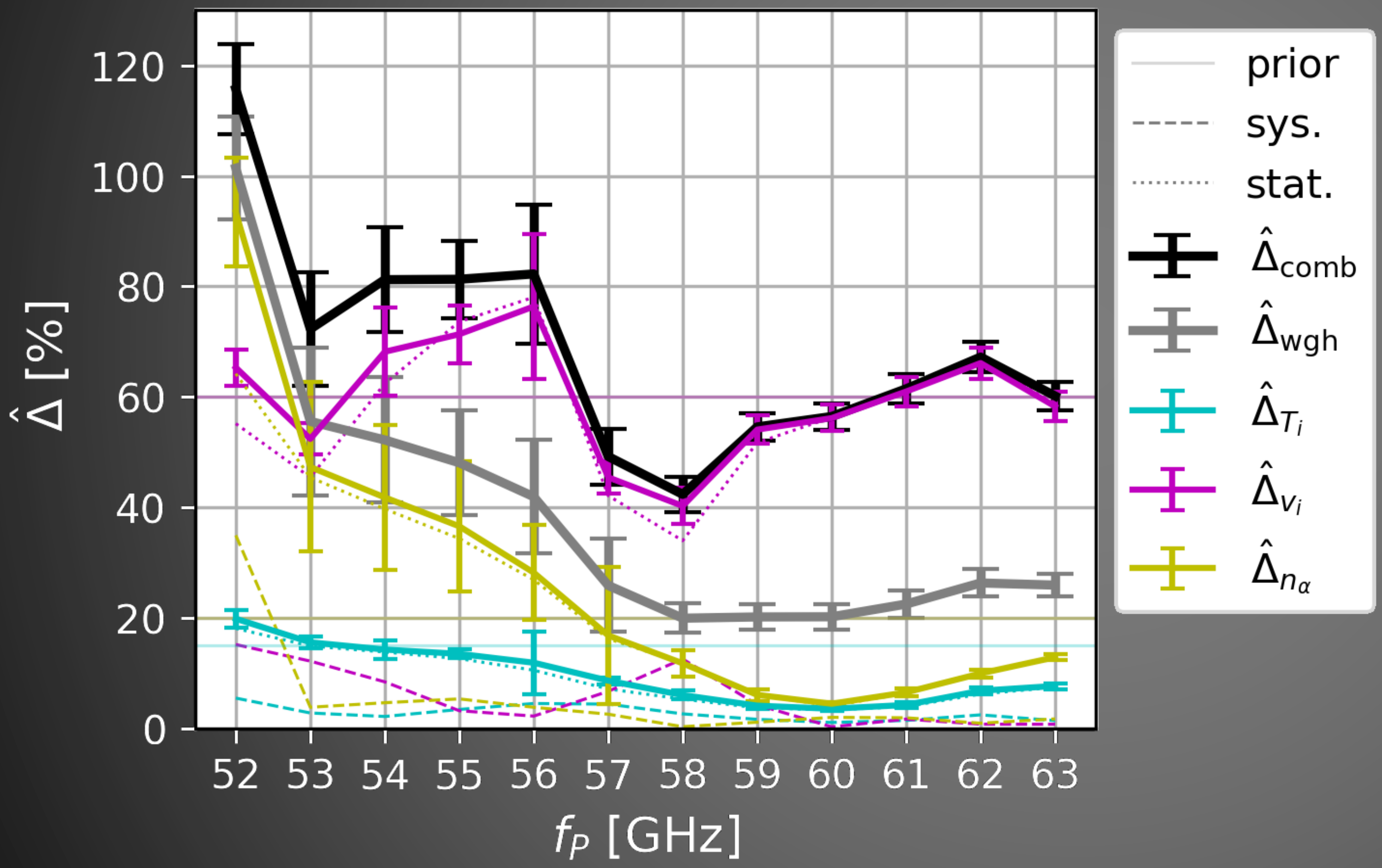

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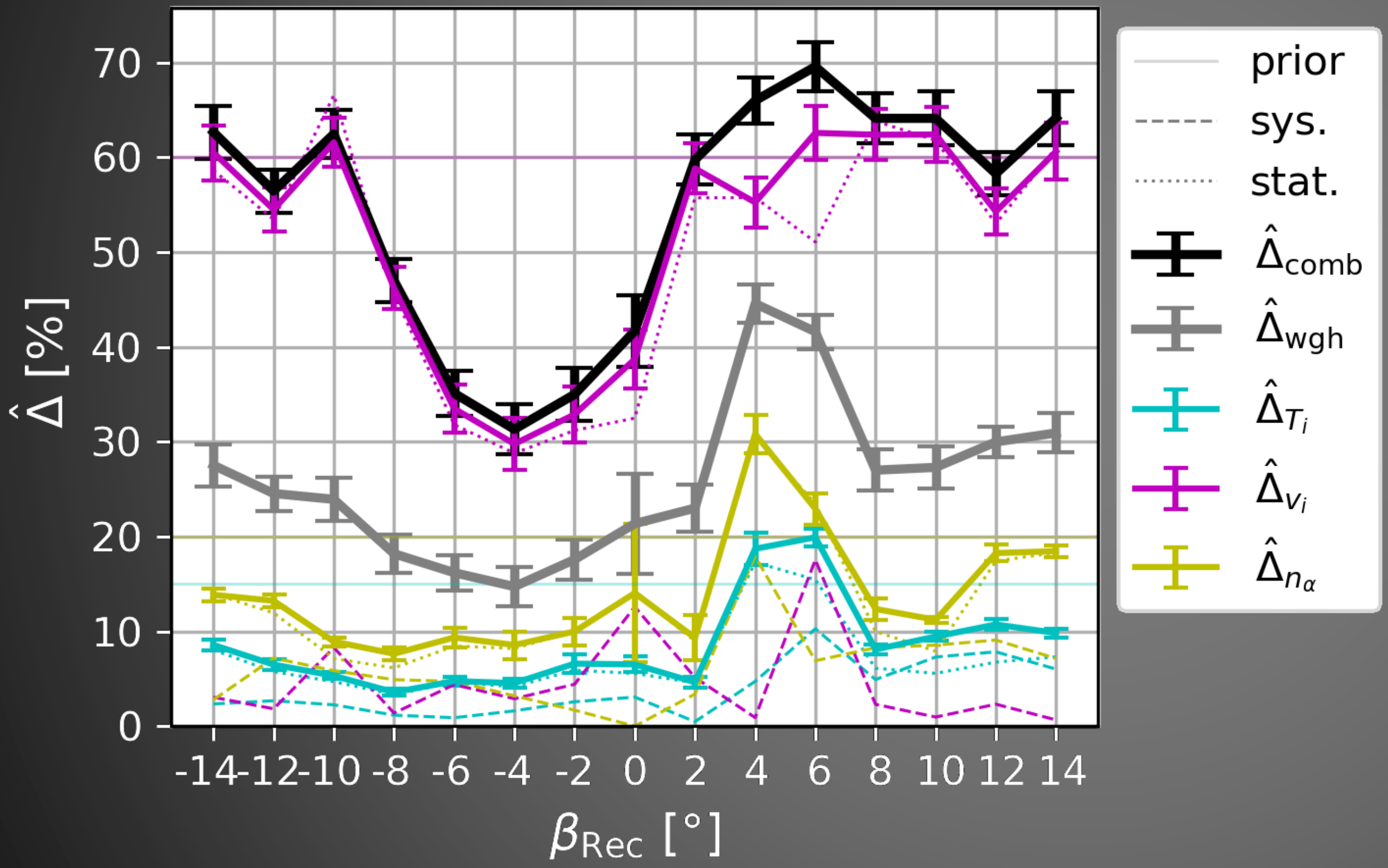

Relative measurement errors $\hat{\Delta}_X$ weighted by prior uncertainties to get $\hat{\Delta}_{\text{wgh}}$

Key trade-offs:

- Lower frequencies mean less ECE noise, but also more refraction
- More parallel view means better V_i sensitivity, but also more ECE noise

Conclusions

- CTS is viable as a core diagnostic for DEMO

- Proof of principle for optimisation procedure

- Current optimal setup uses probe frequency of ~58.5 GHz and slightly oblique receiver
  ⇒ achieves accuracies of $\widehat{\Delta}_{T_i}\sim 5\%$, $\widehat{\Delta}_{V_i}\sim 30\%$ and $\widehat{\Delta}_{n_\alpha}\sim 8\%$

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❖Next steps:

- Improve realism (edge turbulence, variable scenario, ...)
- Consider machine integration
- Beyond DEMO: Apply optimisation procedure to other machines

Questions?

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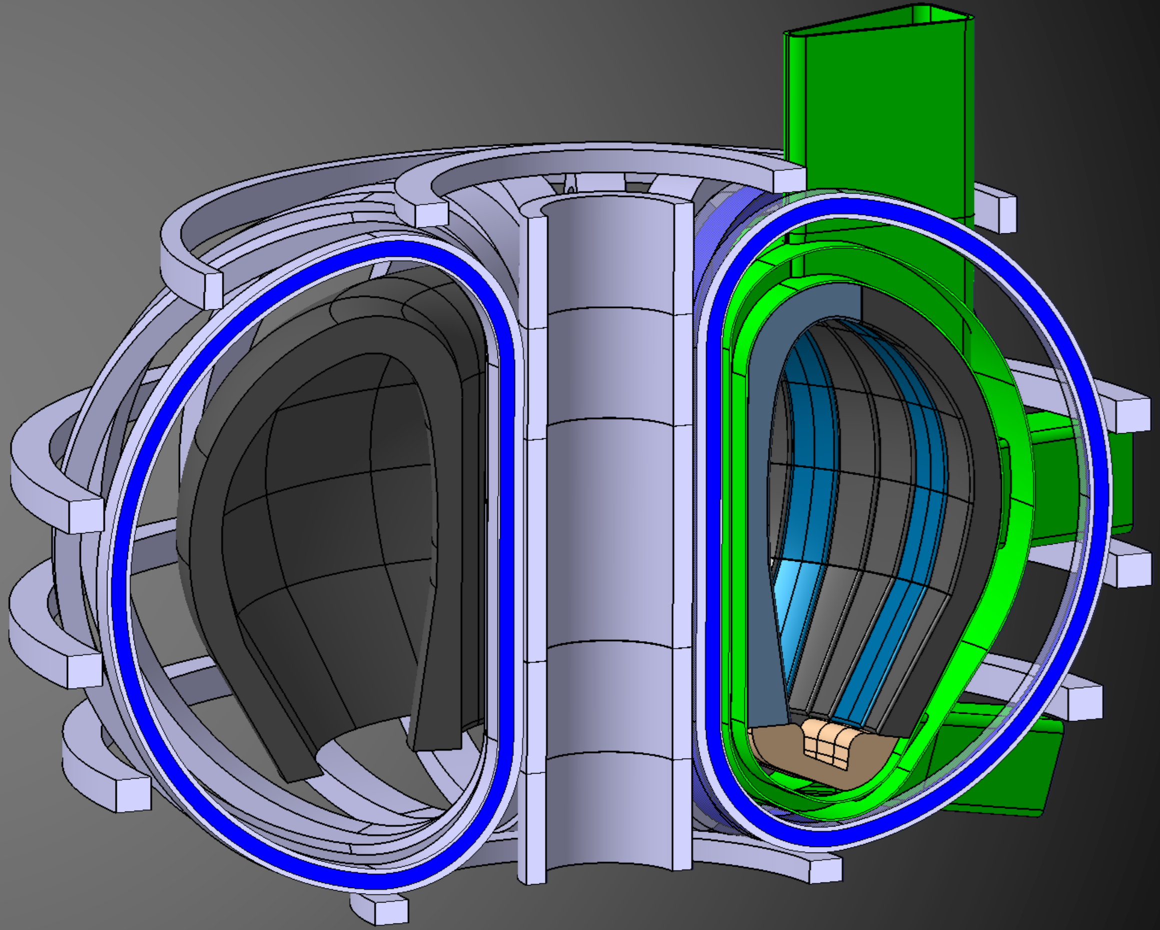
EUROfusion

EU DEMO: Fusion Reactor Conditions

- Large tokamak, ITER-like
- 4.4 T magnetic field on axis
- ~ 30 keV core temperature
- Designed for single operational scenario
  ↪ little variation between discharges
- Extreme neutron irradiation
- Limited diagnostics access
  (breeding blanket)



M. Kannamüller et al., *DEMO LAR – Transforming the 2D design point in 3D CAD models* (12/11/2024)