Synthetic Diagnostics: Present and Future

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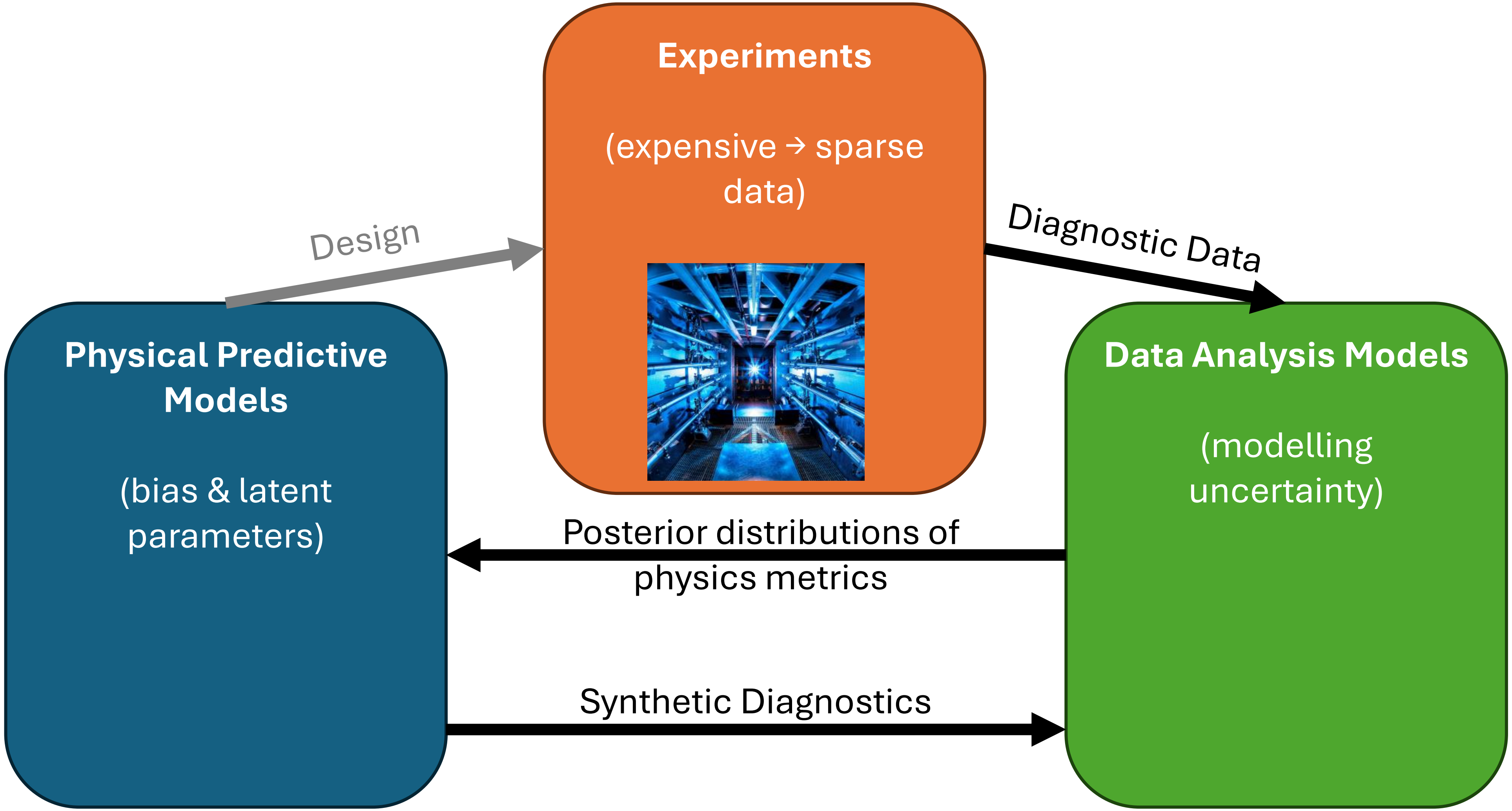
Synthetic diagnostics

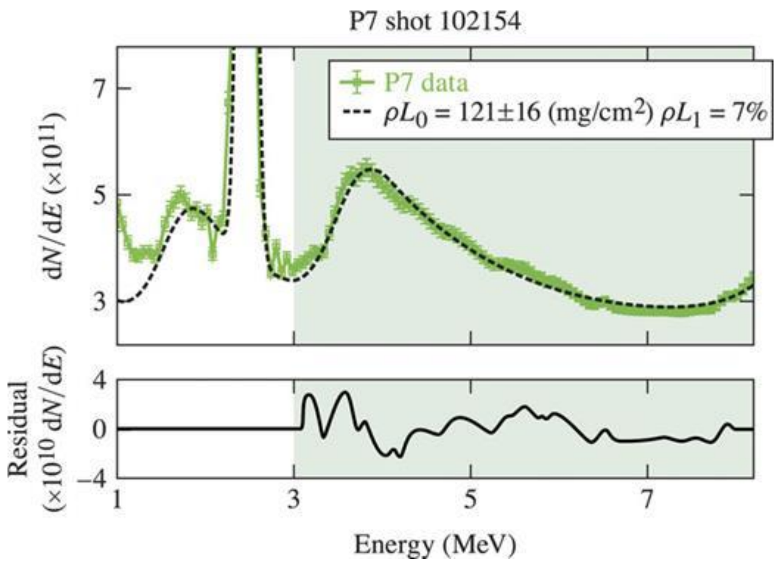
In short: *a way to include our numerical predictions in experimental data analysis*



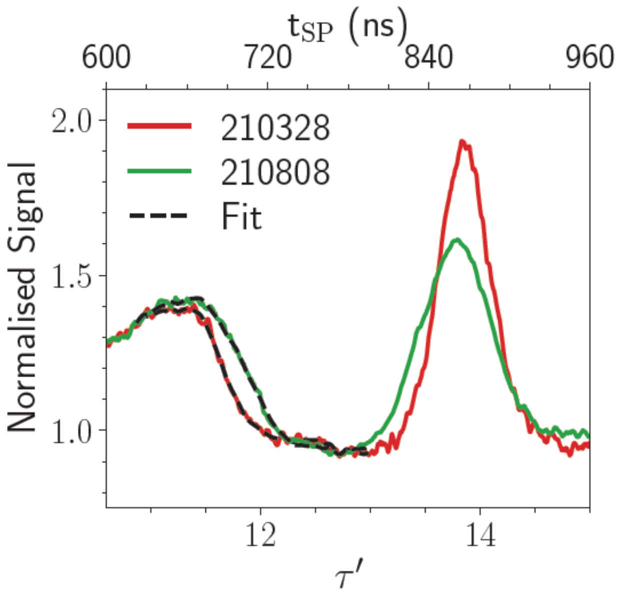
Current state of synthetic diagnostics

- UK very strong lead in ICF synthetic neutron diagnostics
  - ICL analysis codes used for OMEGA and NIF nToF data
- IFE neutron spectrum vs MFE neutron spectrum, balance of plant

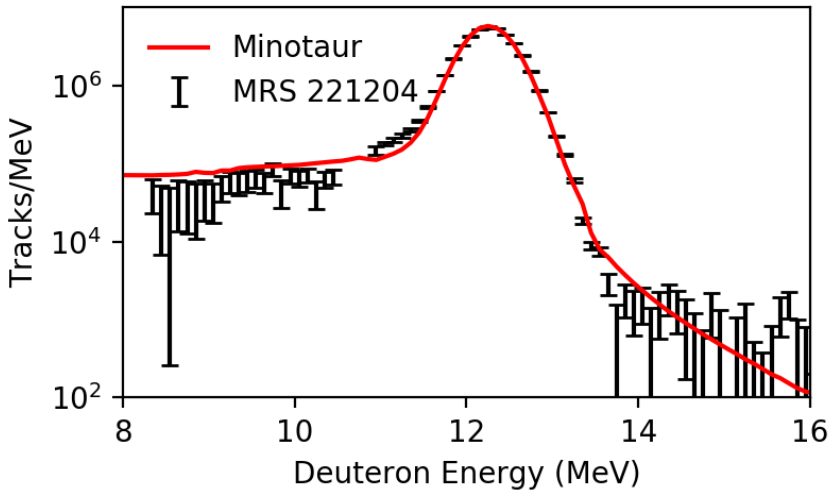
OMEGA: Areal density asymmetries and backscatter



NIF: Backscatter



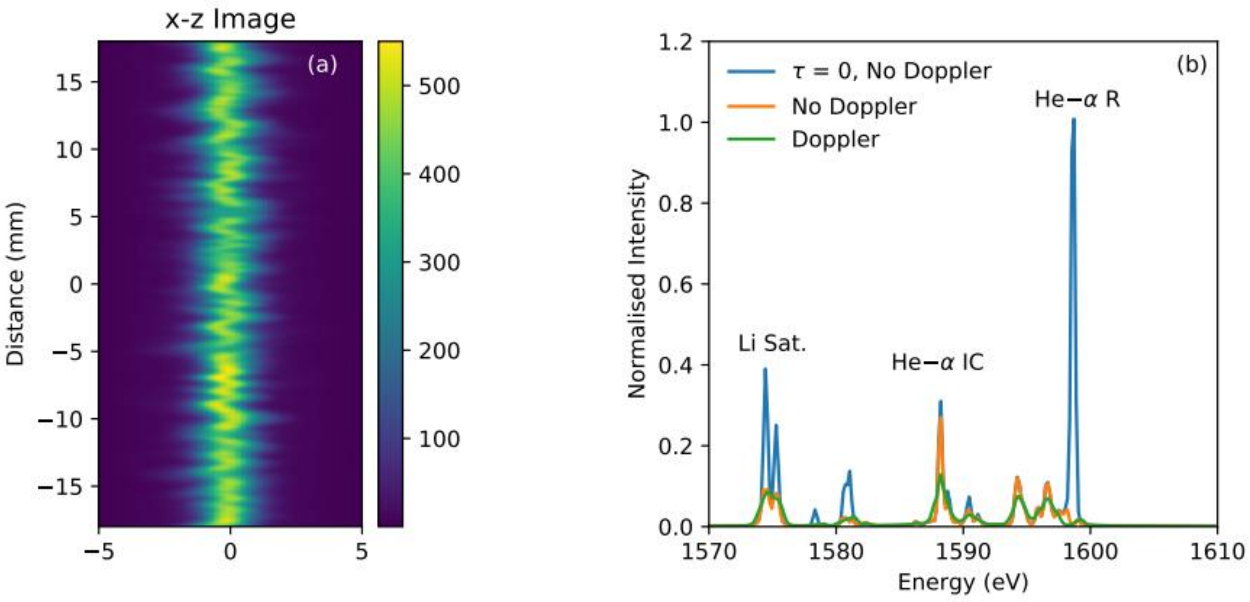
NIF: Alpha and neutron knock-ons



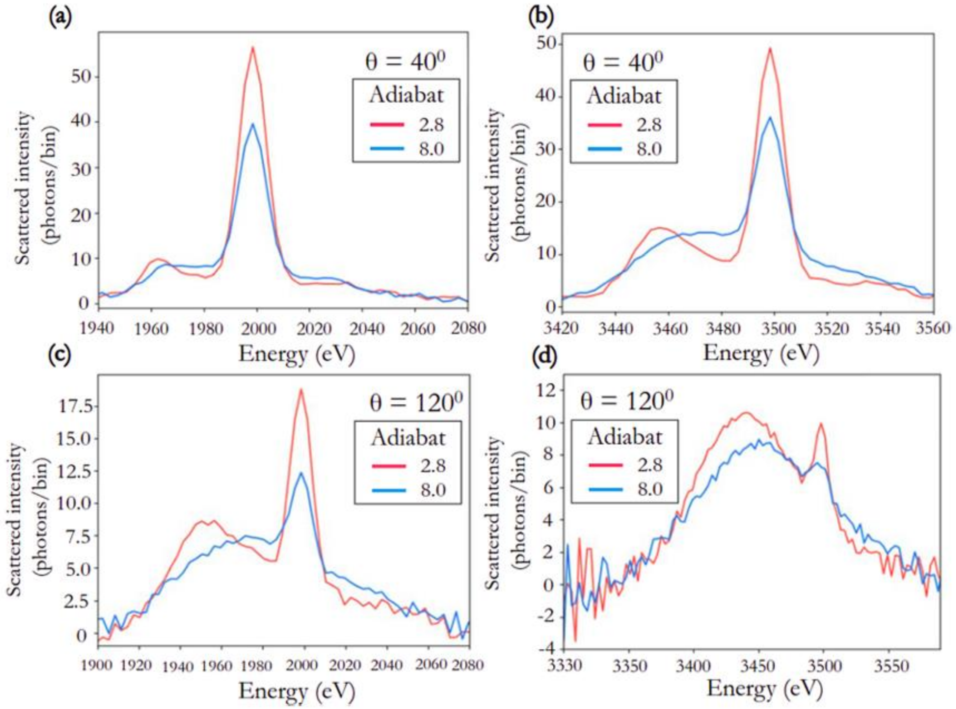
Current state of synthetic diagnostics

- Other UK led simulation and synthetic diagnostics

MARZ: X-ray imaging and spectroscopy



OMEGA: X-ray Thomson Scattering



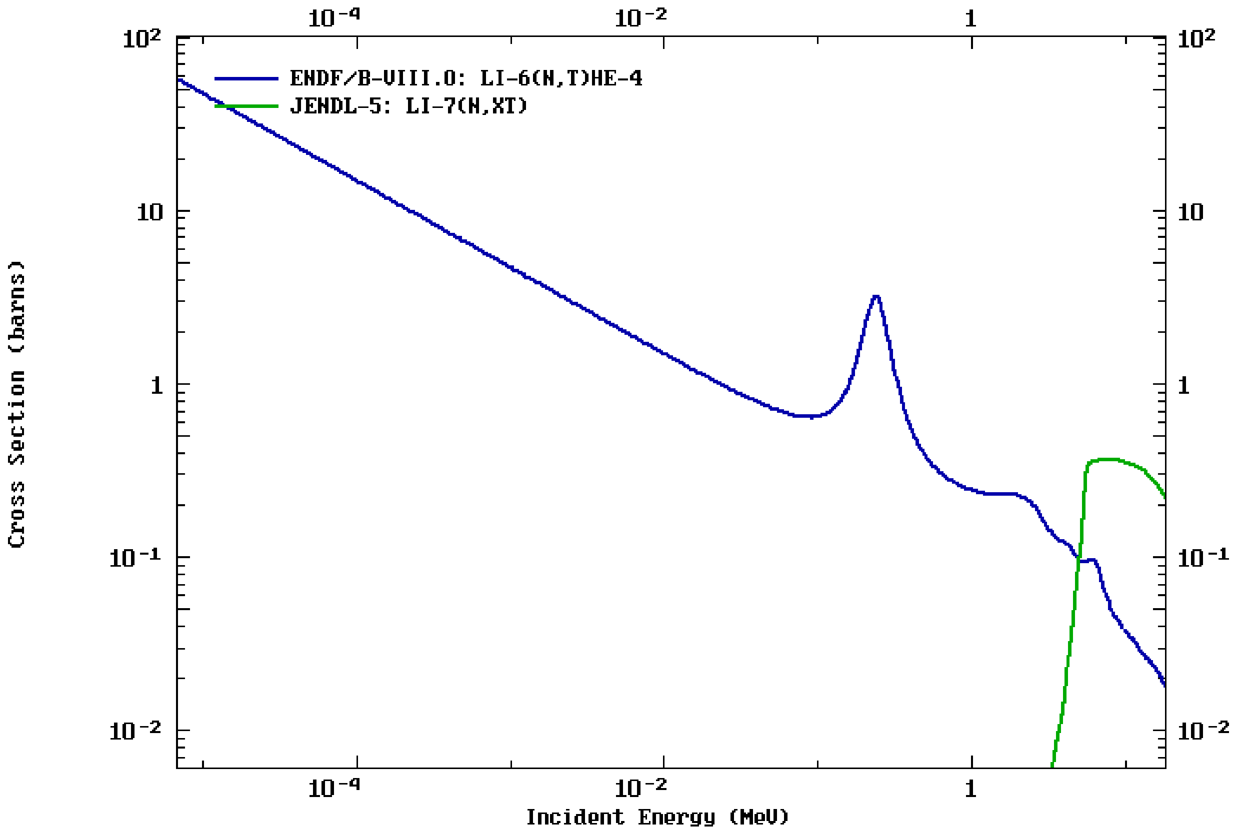
Looking forward: IFE diagnostics

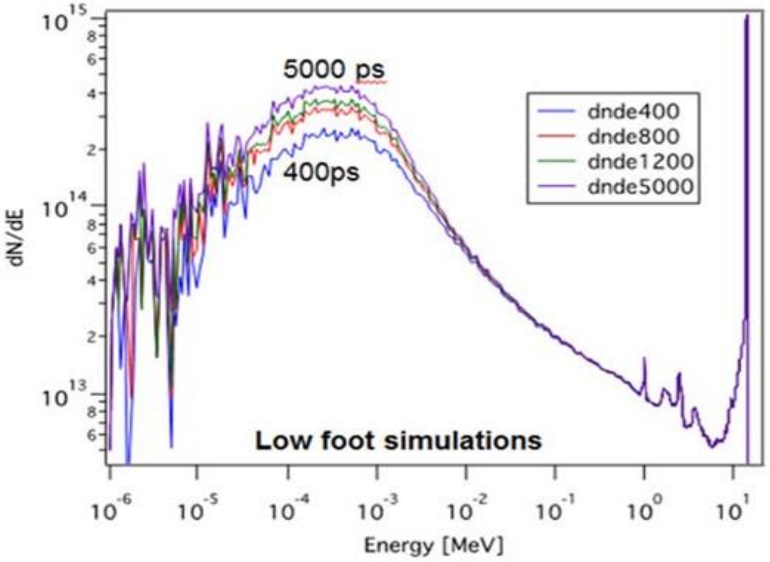
1. Yield optimisation and the path to high gain
    - Burn propagation
    - Burning plasma failure modes
2. High yield fusion particle fluxes
    - Tritium breeding
    - First wall interaction
    - Coupling to reactor fluid
3. Rep-rate
    - Automated diagnostic data retrieval and analysis

Looking forward: IFE diagnostics

High yield particle fluxes:

- Low energy neutrons
  - In-target moderation reduces neutron damage
  - Increases $^{6}Li(n,T)\alpha$ yield
  - No reliable/realistic modelling capability

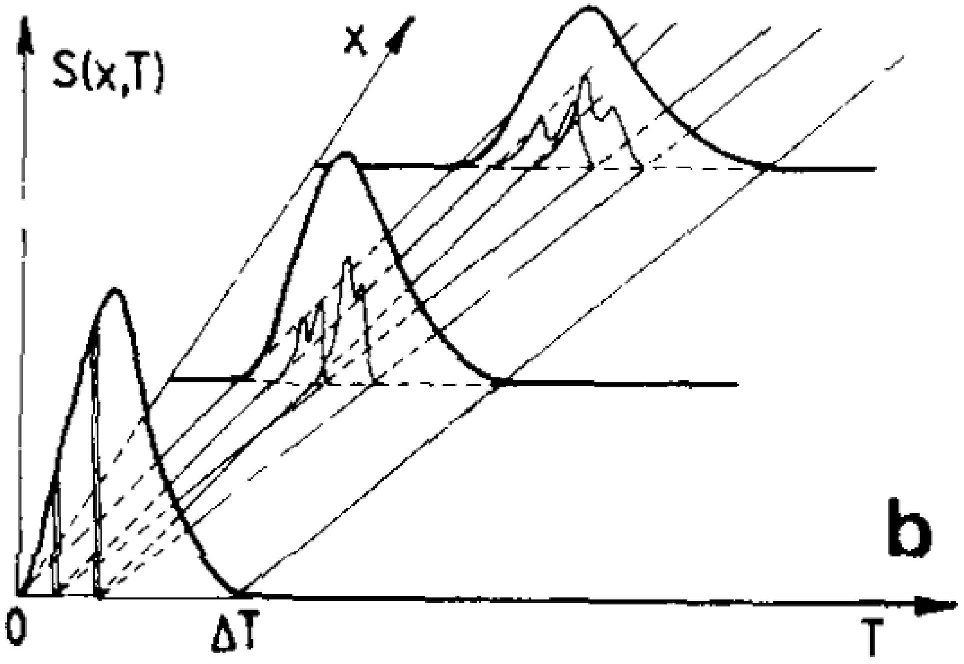




Looking forward: IFE diagnostics

Path to high gain:

- Time resolved traditional neutron spectroscopy
  - Leverage expertise in nToF, rad-hydro modelling and inference



Time scales

- NIF (the luxury of time, the curse of sparse data):

$$t_{campaign} > \ t_{shot} > t_{data} > t_{design}$$

  - Human-led analysis and (2D) design is entirely feasible and advantageous

- OMEGA:

$$t_{campaign} > t_{shot} \sim t_{data} \sim t_{design}$$

  - Some data retrieval automated, e.g. nToF, “authorised” by staff
  - Some data has significant analysis time e.g. CR-39
  - Highly optimised 1D design just about possible on cyro schedule

Time scales

- Hypothetical: OMEGA once every 45 min → once every 5 mins:

$$t_{shot} < t_{data} \ll t_{design} \backsim t_{campaign}$$

  - Some diagnostics methods poorly suited due long analysis times
  - Hydro models cannot re-design on the shot day

ELI L4n, max rep rate 1 shot/min

Investigation of laser plasma instabilities driven by 527 nm laser pulses relevant for direct drive inertial confinement fusion

We report on a study of laser plasma instabilities with 527 nm laser pulses in an intensity range of 0.5×10^{13} - 1.1×10^{15} Wcm^{-2} and plasma parameters entering a regime that is relevant for direct drive inertial confinement fusion. Using the kilojoule high repetition rate L4n laser at the Extreme Light Infrastructure—Beamlines, more than 1300 shots were collected, and the onset and the growth of stimulated Brioullin scattering (SBS) and stimulated Raman scattering (SRS) were

Rep-rate analysis

- Automation of data analysis
  - Significant challenge in diagnostic drift, calibration, failure detection

- Rep-rate design
  - Can design in lead time to experiment using traditional methods
  - But rep-rate gives unique opportunity for on-day optimisation!
    - Surrogates, statistical, differentiable models