



Bayesian integrated equilibrium reconstruction at WEST using magnetic, density and temperature diagnostics

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WEST #58089, $t = 42.356s$ (flat-top)

Bayesian integrated, uncertainty-aware equilibrium reconstruction

The what and why

Plasma state and confidence:

- Plasma shape
- Internal current distribution
- Kinetic profiles
- Posterior uncertainties

Two drivers:

- Reactors: fewer diagnostics, harsher environment
- Reliable control: uncertainties matter

Bayesian framework

For every inferred profile m :

- Diagnostic values D
- Linear forward model F
- Gaussian meas. errors ε

$$D = Fm + \varepsilon$$

Gaussian prior and likelihood \Rightarrow analytic Gaussian posterior

- Closed-form, fast
- Full uncertainties

$$p(m|D) = \frac{p(D|m)p(m)}{p(D)}$$

Conclusion & outlook

Now:

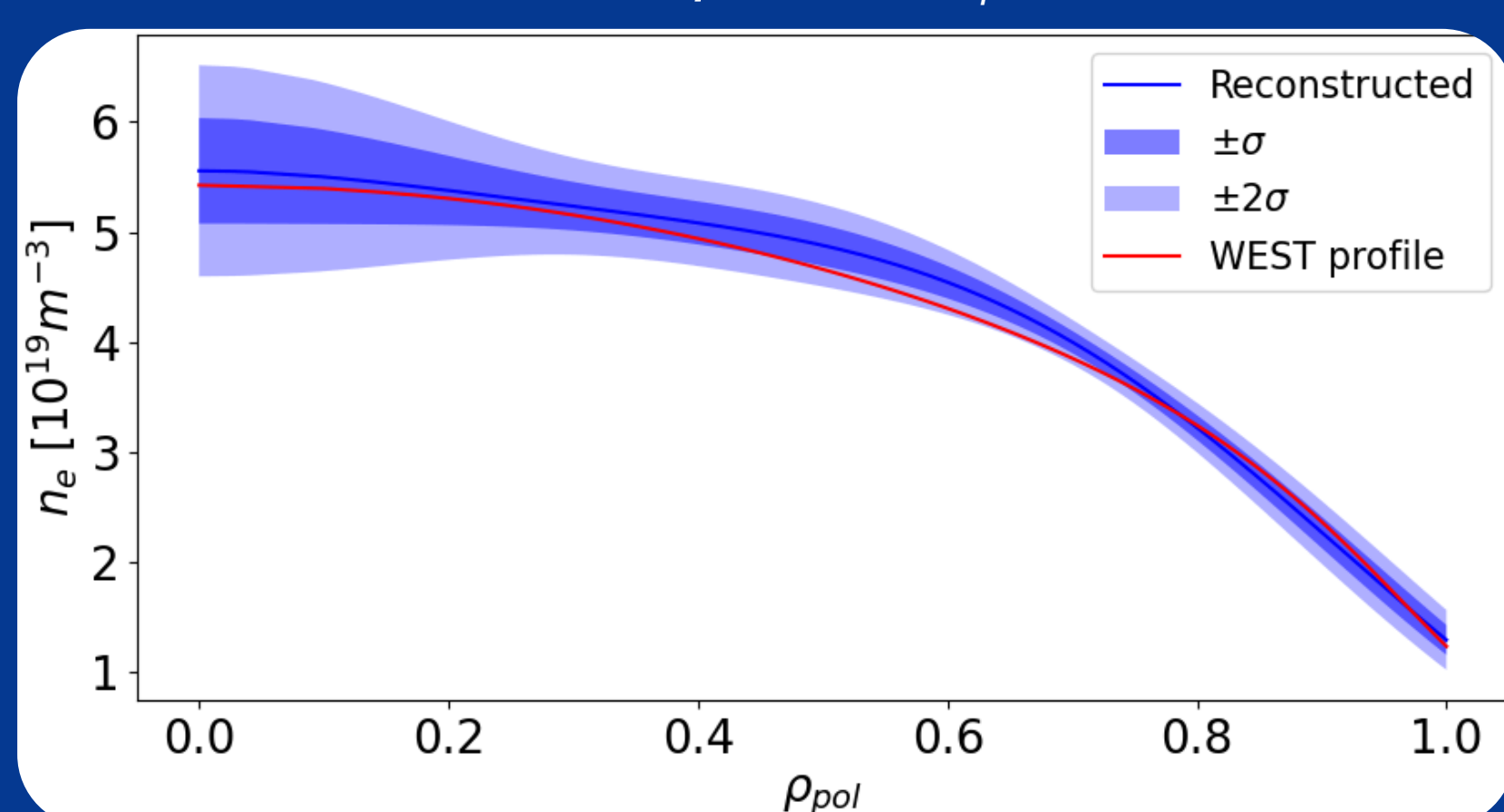
- Integrated diagnostic suite
- Coupled via Grad-Shafranov
- J_ϕ, ψ, n_e, T_e + uncertainties
- Matches NICE and VacTH

Next:

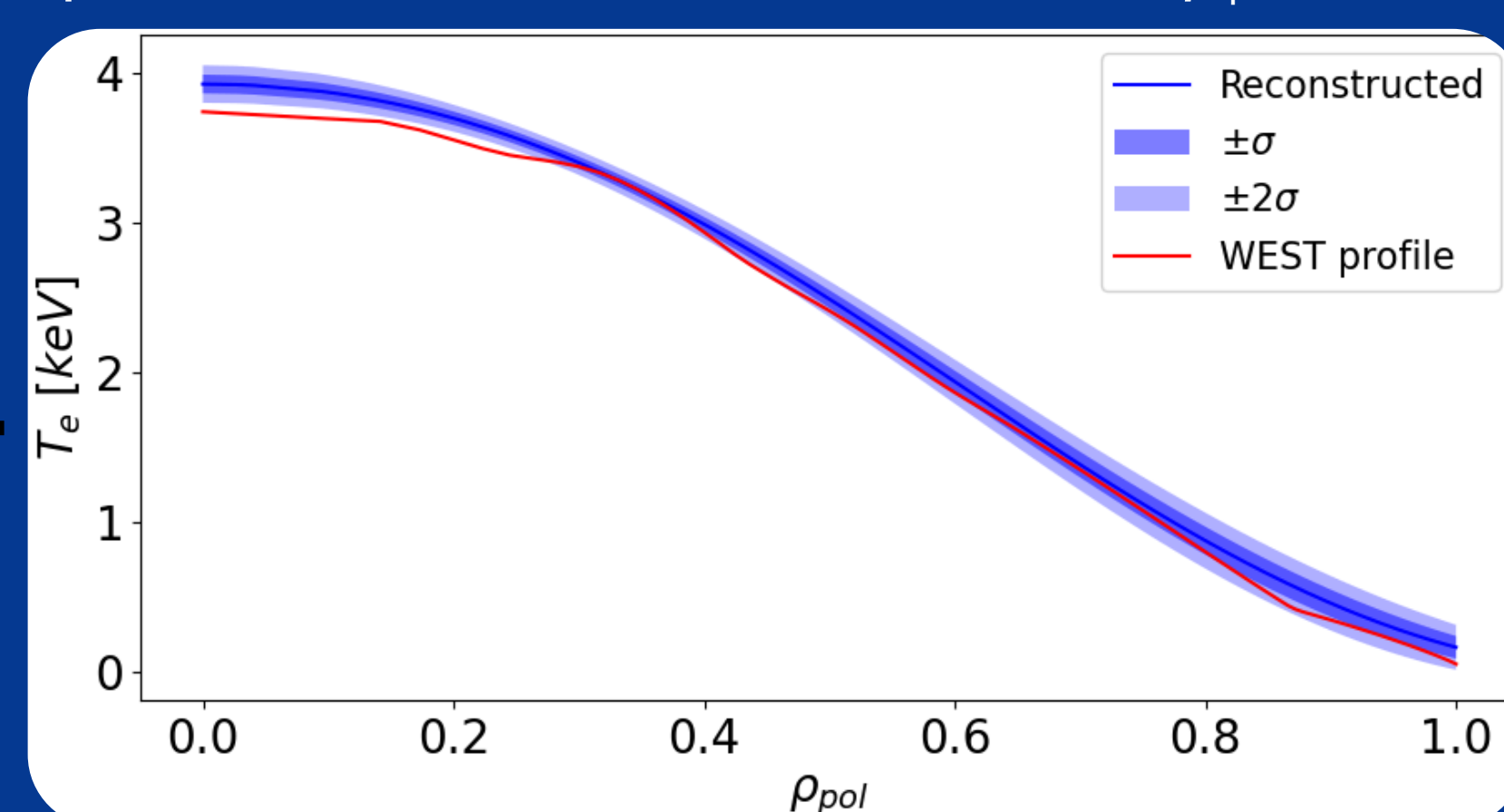
- $\alpha(\rho_{pol})$; infer T_i, n_i
- Infer magnetic pressure
- Single-step joint inference

Kinetic profiles coupled through Grad-Shafranov equation

Poloidal flux ψ from J_ϕ inference constrains n_e, T_e profiles to 1-D reconstructions in ρ_{pol}



Density profile agrees well, with slightly weaker match in core-edge transition



Temperature has expected but consistently higher shape due to known WEST ECE drifts

$$J_\phi = R \frac{\partial p}{\partial \psi} + \frac{\mu_0}{R} \Phi \frac{\partial \Phi}{\partial \psi}, p = (1 + \alpha) n_e T_e$$

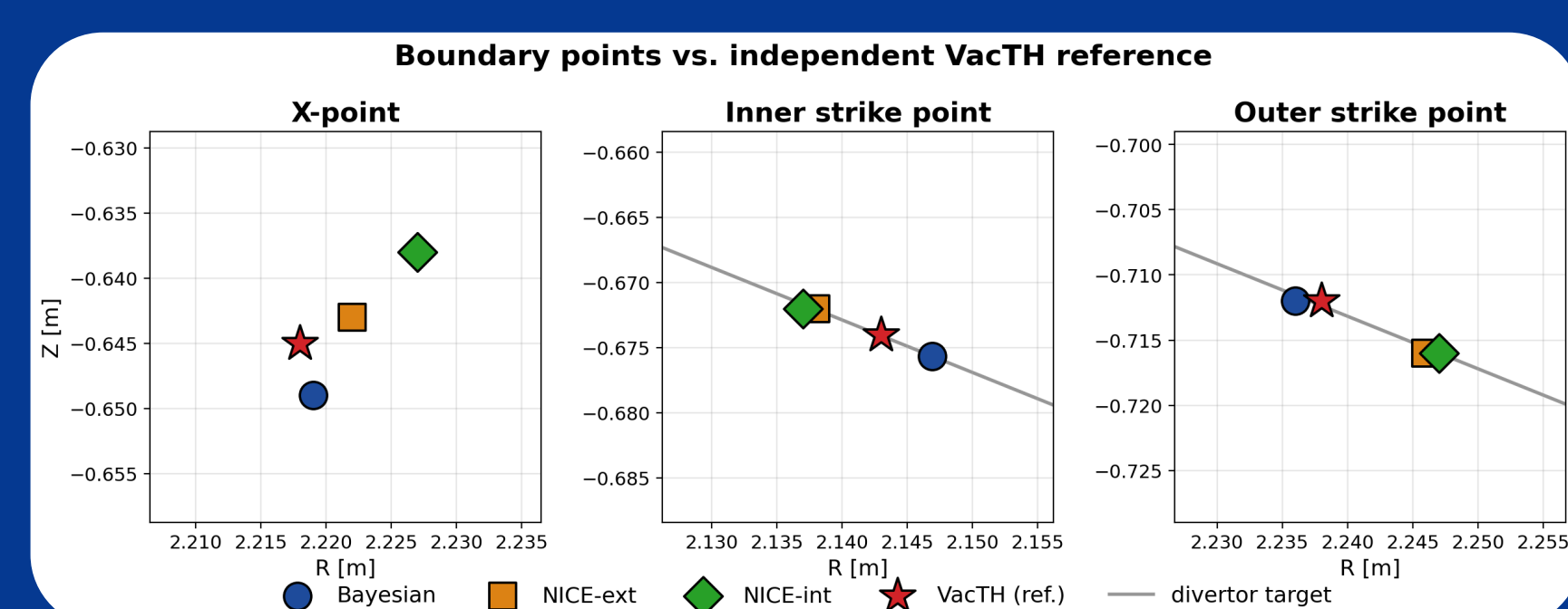
Grad-Shafranov turns n_e, T_e into a virtual diagnostic of J_ϕ

Ions enter through the hyperparameter α , the ion-to-electron pressure ratio

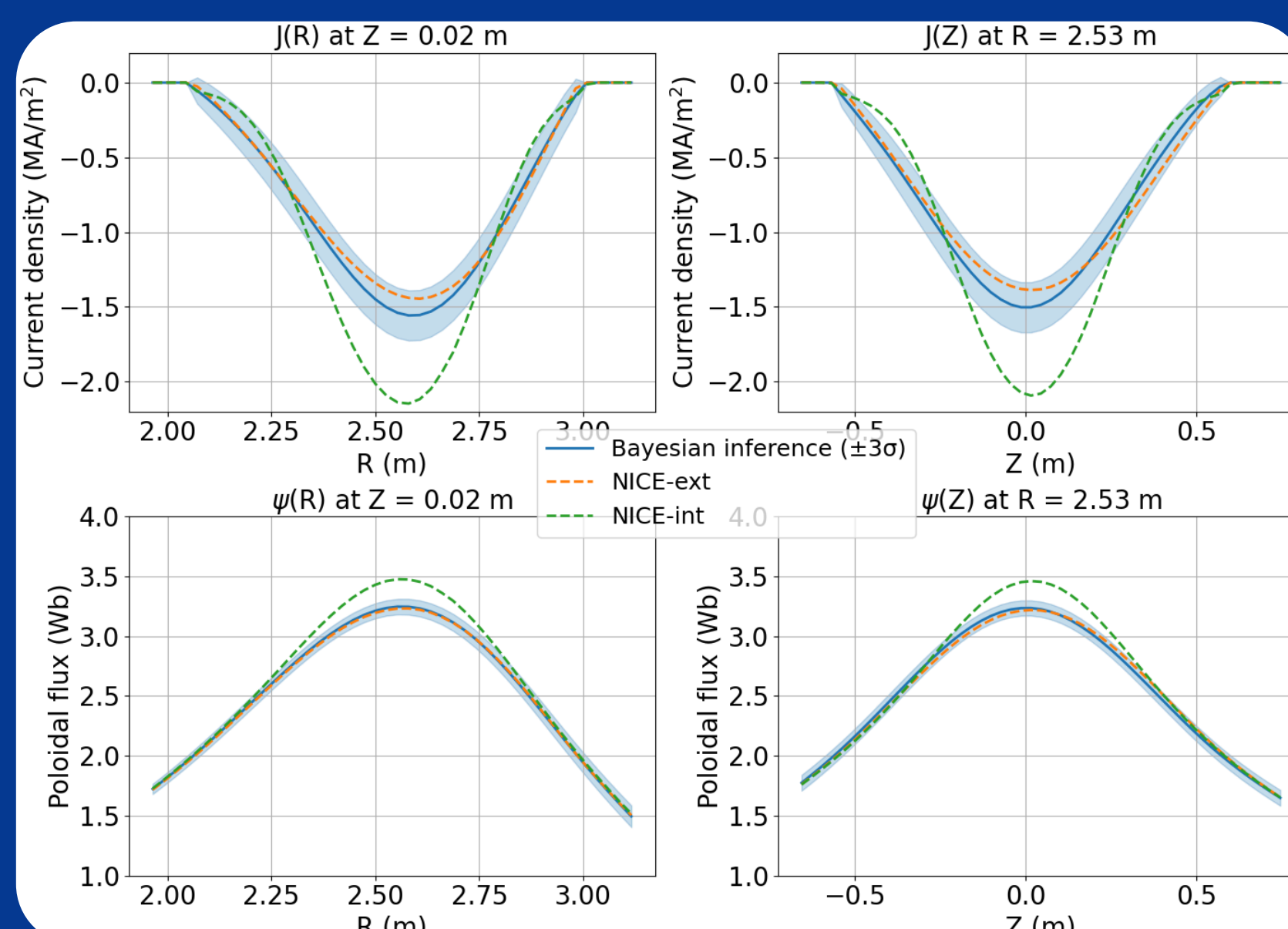
Current density & flux: benchmarking against NICE and VacTH

Compare with NICE (ext: external magnetics; int: + interfero-polarimetry) and VacTH plasma boundary

- Total plasma current: $\sim 0.6\%$ vs NICE
- Flux at X-point: $\sim 0.1\%$ vs NICE
- Unlike NICE: every quantity has uncertainty



- Large NICE-int X-point distance of 1.1cm
- NICE strike points: 0.6 and 0.9cm
- Bayesian closest to VacTH (~ 0.4 cm)



- Core J_ϕ : good agreement with NICE-ext
- Flux ψ : excellent agreement with NICE-ext
- Large NICE spread in core (-1.4 to -2.2 MA/m²)

The iterative loop

Start from external magnetics

Step 0

External-only J_ϕ

pick-up coils + flux loops
non-stationary CAR prior

Infer the kinetic profiles

Step 1

Kinetic profiles

n_e (interf.), T_e (ECE)
1-D SE prior in ρ_{pol}

End with internal physics

Step 2

J_ϕ + internal info

GS virtual diag.
+ polarimetry

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