# Optimizing fusion power plant designs for +/- triangularity through FUSE simulations

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APS-DPP, Atlanta
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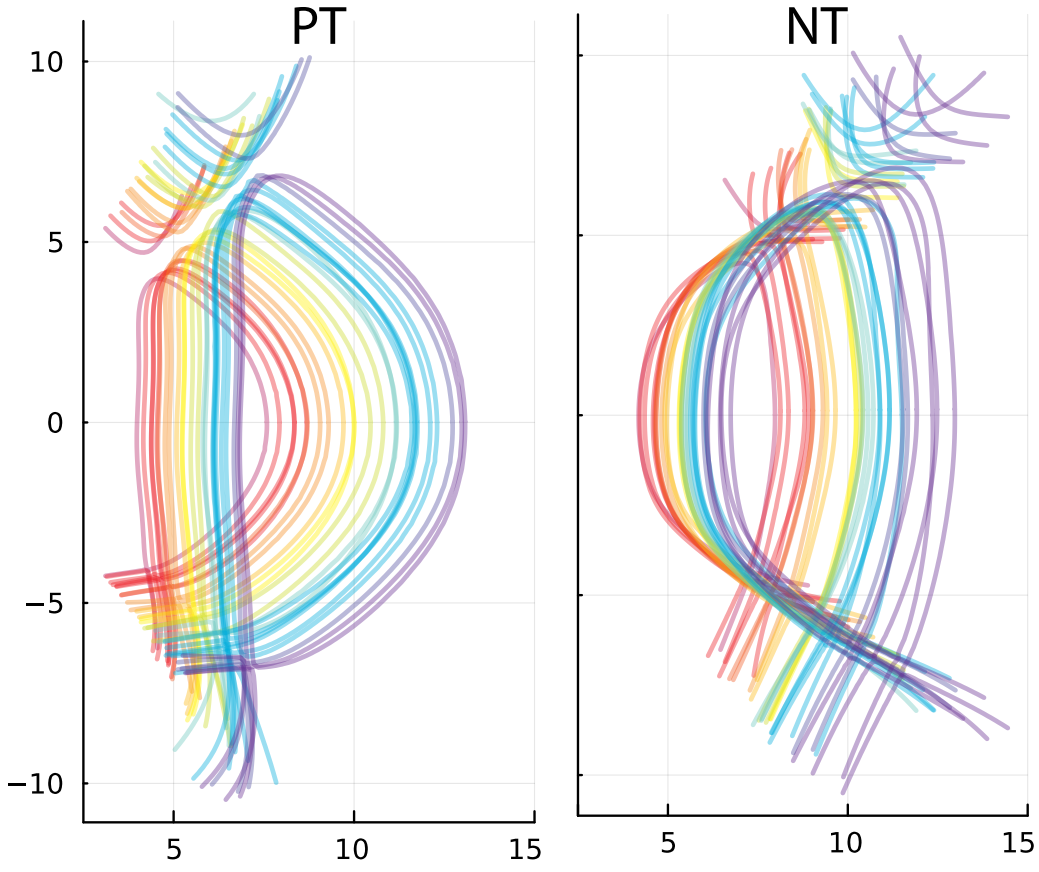


fuse

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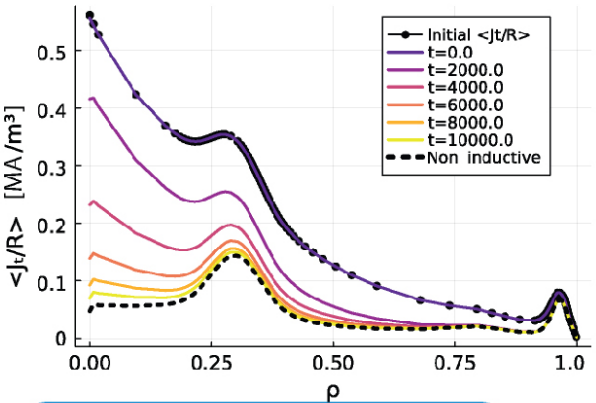
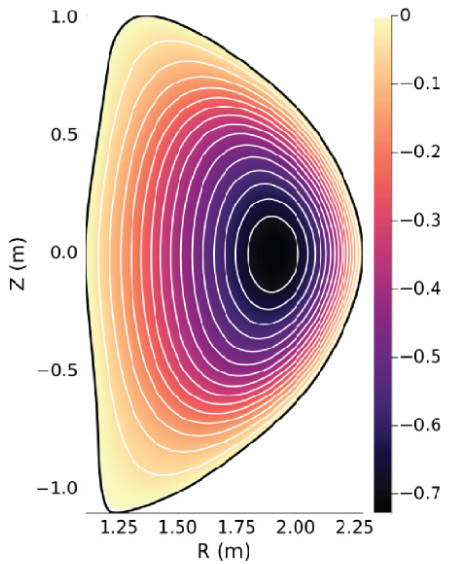
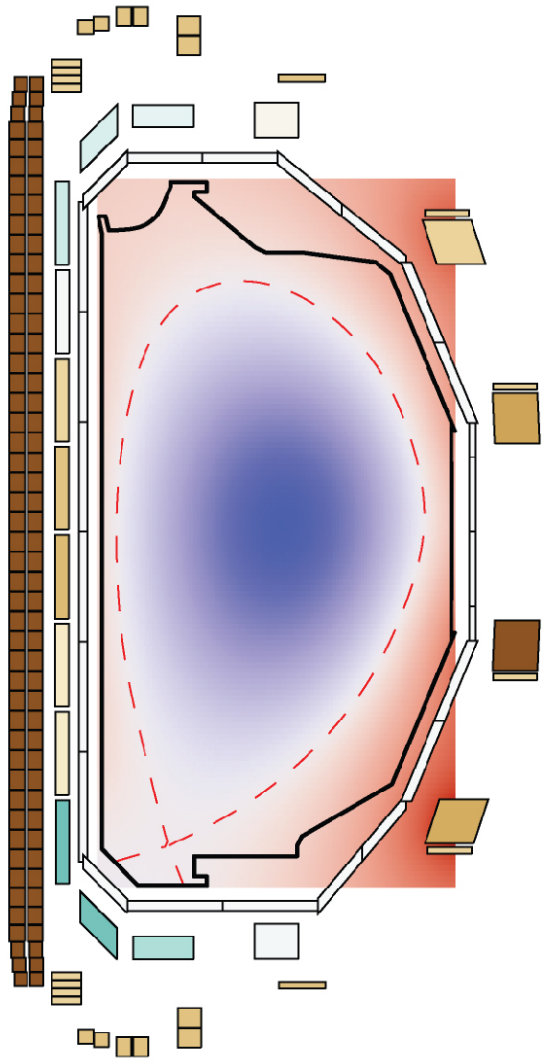
# FUsion Synthesis Engine is a new modeling framework that enables rapid and accurate machine designs

Current evolution



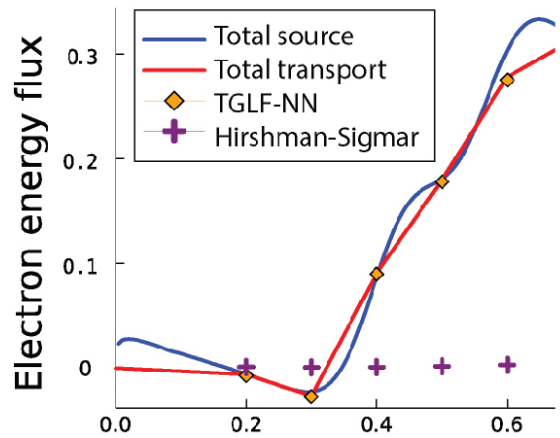

Fixed boundary equilibrium



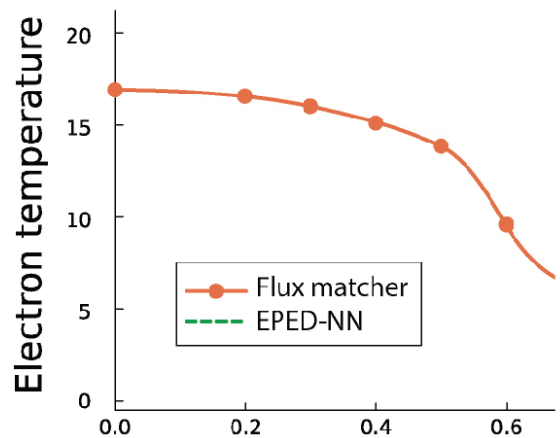



Free boundary equilibrium
w/ coil + passive couplings

Flux-Matching transport wit




Core-pedestal coupling wit





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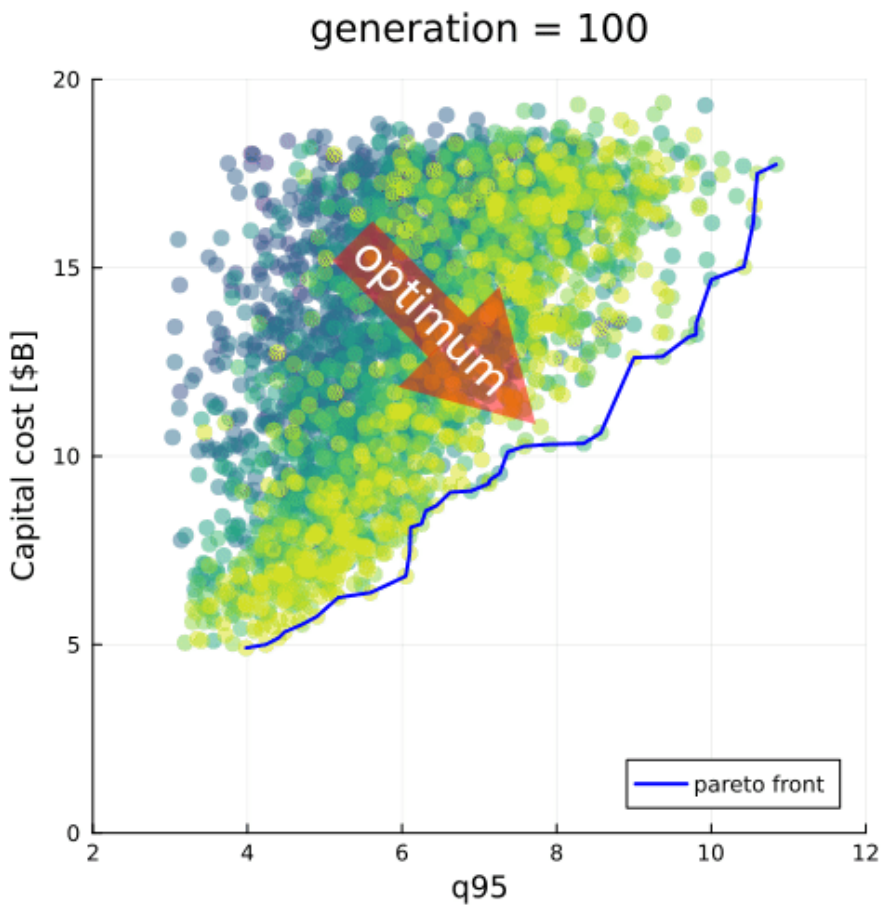
# FUSE allows you to rapidly compare consistent designs on the same footing

- **Multi-objective constrained optimization** workflows enable designs exploration and trade study
- **Genetic algorithm** steers solution towards the Pareto front
- Helps different stakeholders **identify a target design**
  (scientists, investors, policymakers,... )
- **Scalable parallel execution** runs 100k+ cases in few hours on small cluster



# Trade study for positive-$\delta$ VS negative-$\delta$ FPP by running separate optimizations and compare pareto fronts

**OBJECTIVES**

1. min capital cost
2. max $q_{95}$ (safety factor)

**CONSTRAINTS**

- $P_{\text{net, elec}} = 250 \pm 50$ MW
- flattop $= 1.0 \pm 0.1$ (h)
- TBR $= 1.1 \pm 0.1$
- $P_{\text{sol}}/P_{\text{LH}} > 1.1$ (for $+\delta$)
- $P_{\text{sol}}/R < 15$ (MW/m)

**ACTUATORS**

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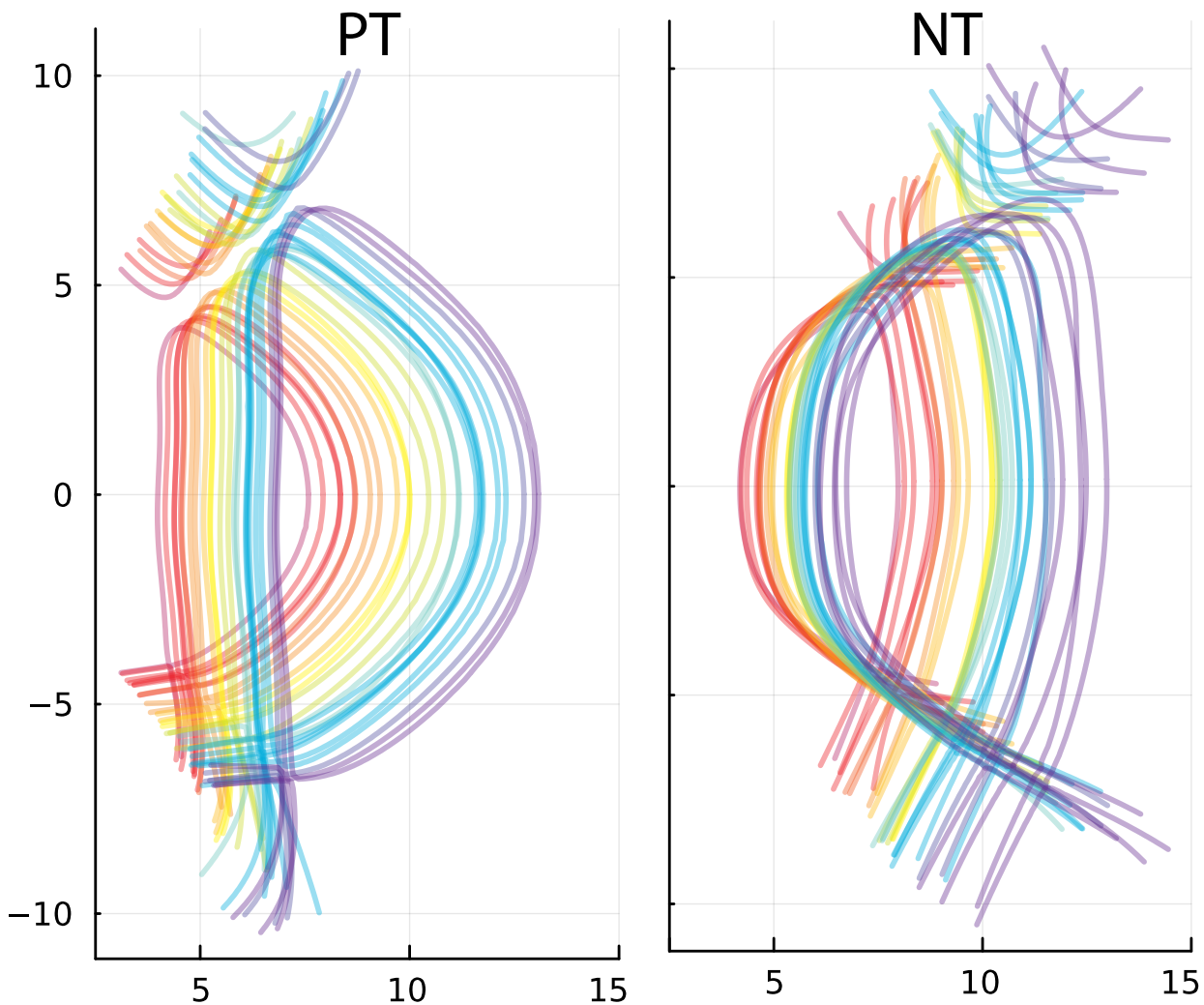






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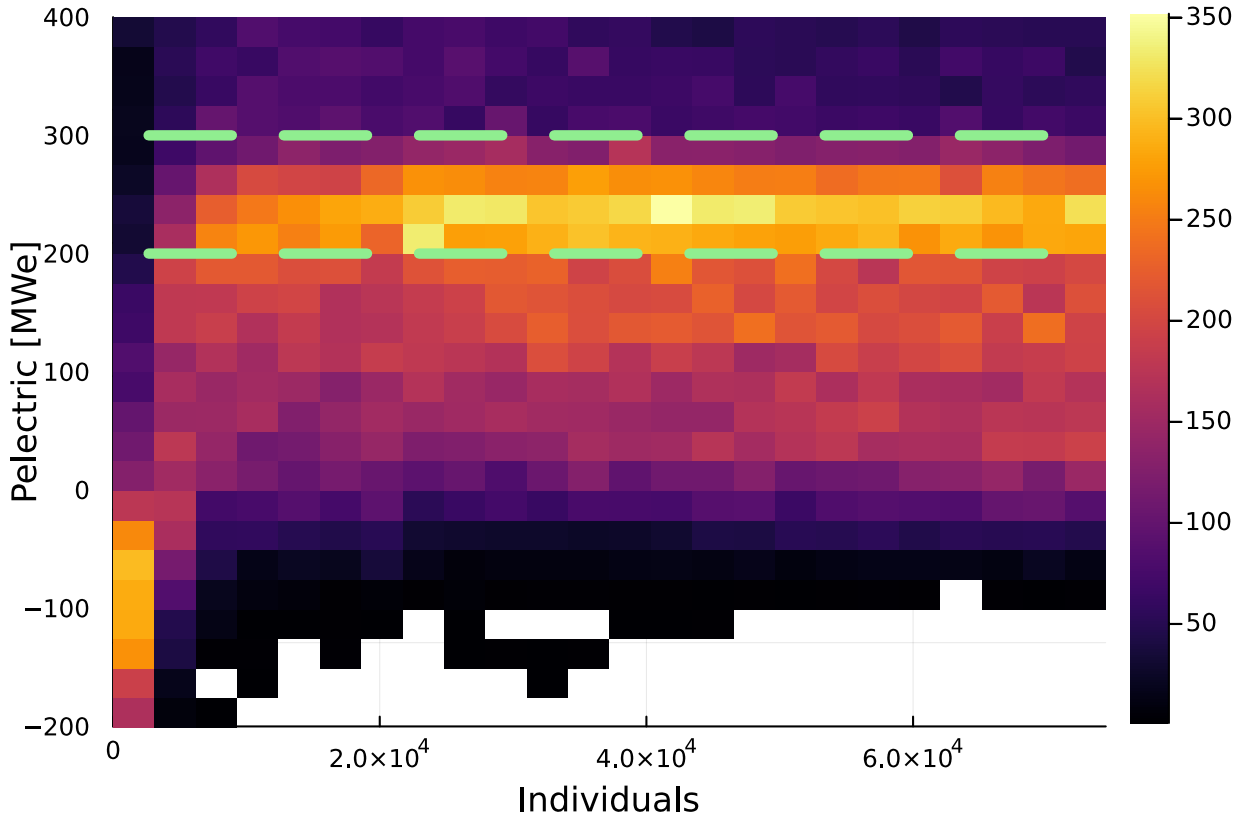


2×50k+ runs, **each a full FPP design**

- 1.5D transport + build + eng + bop + cost





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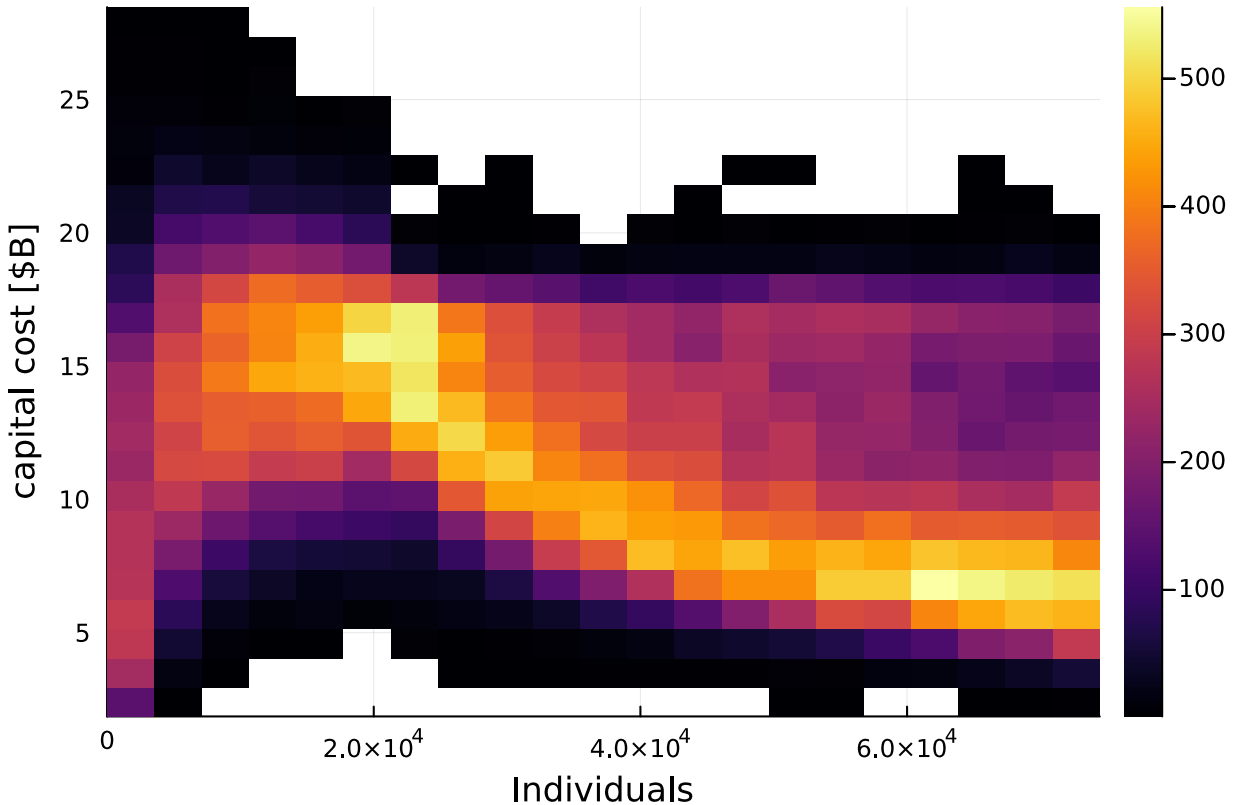


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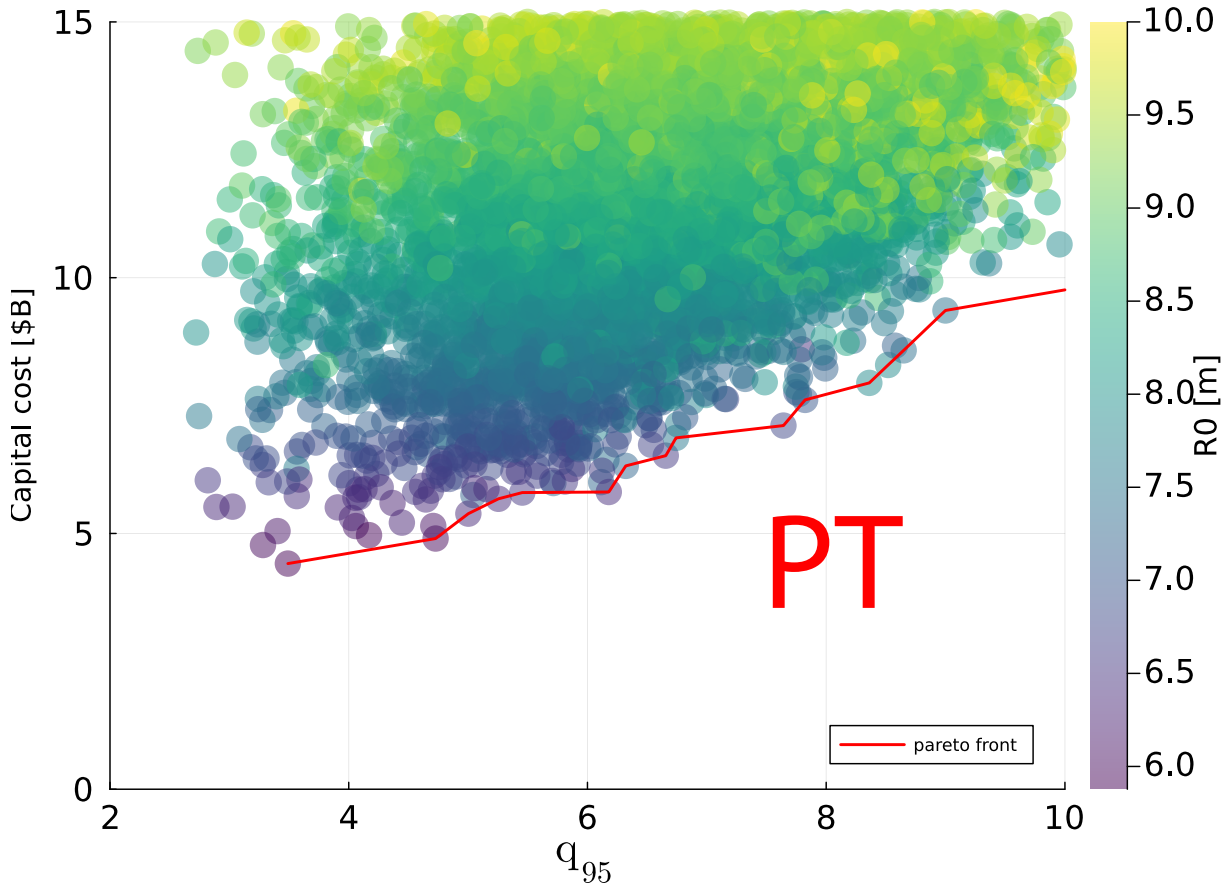


Plasma safety can be bought with:

- Larger devices





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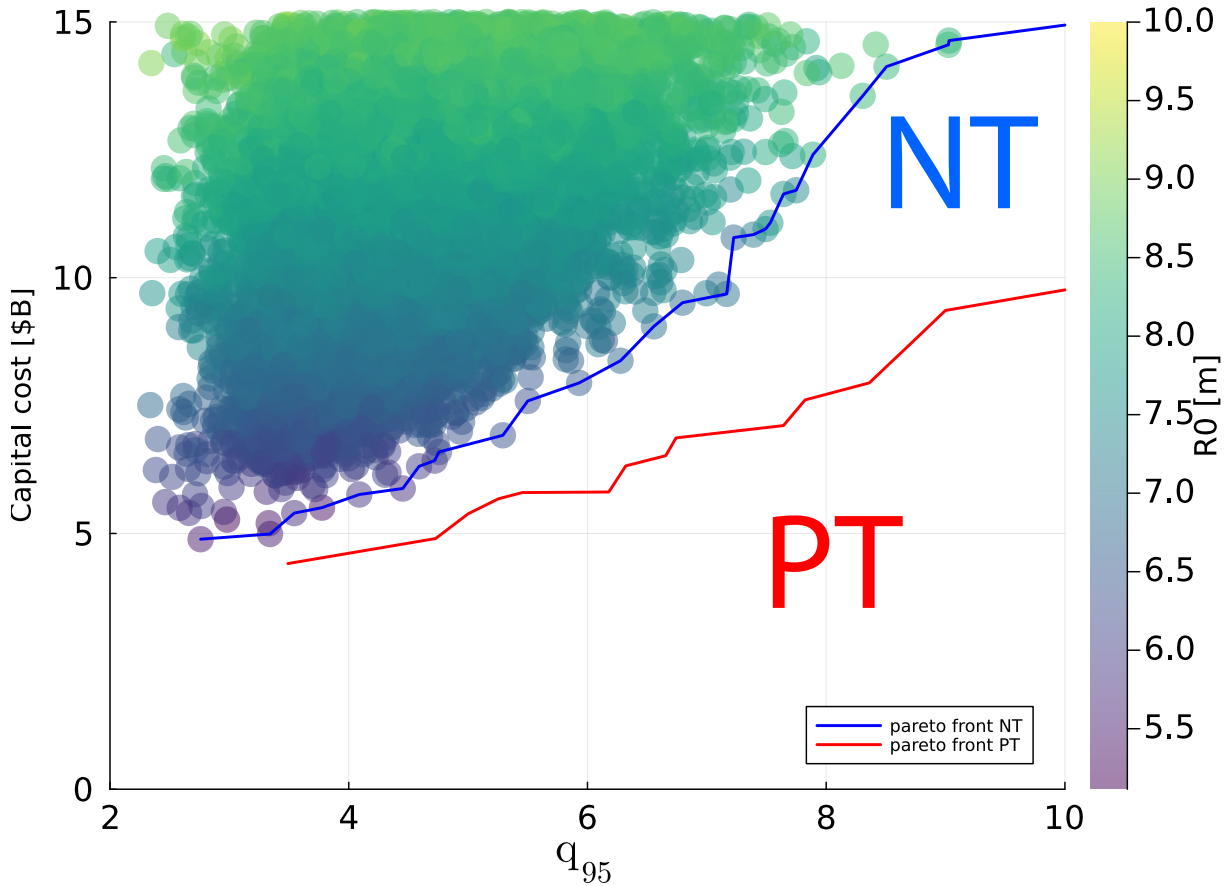


NT and PT are comparable for low q95 but NT scales less favorably with plasma safety factor

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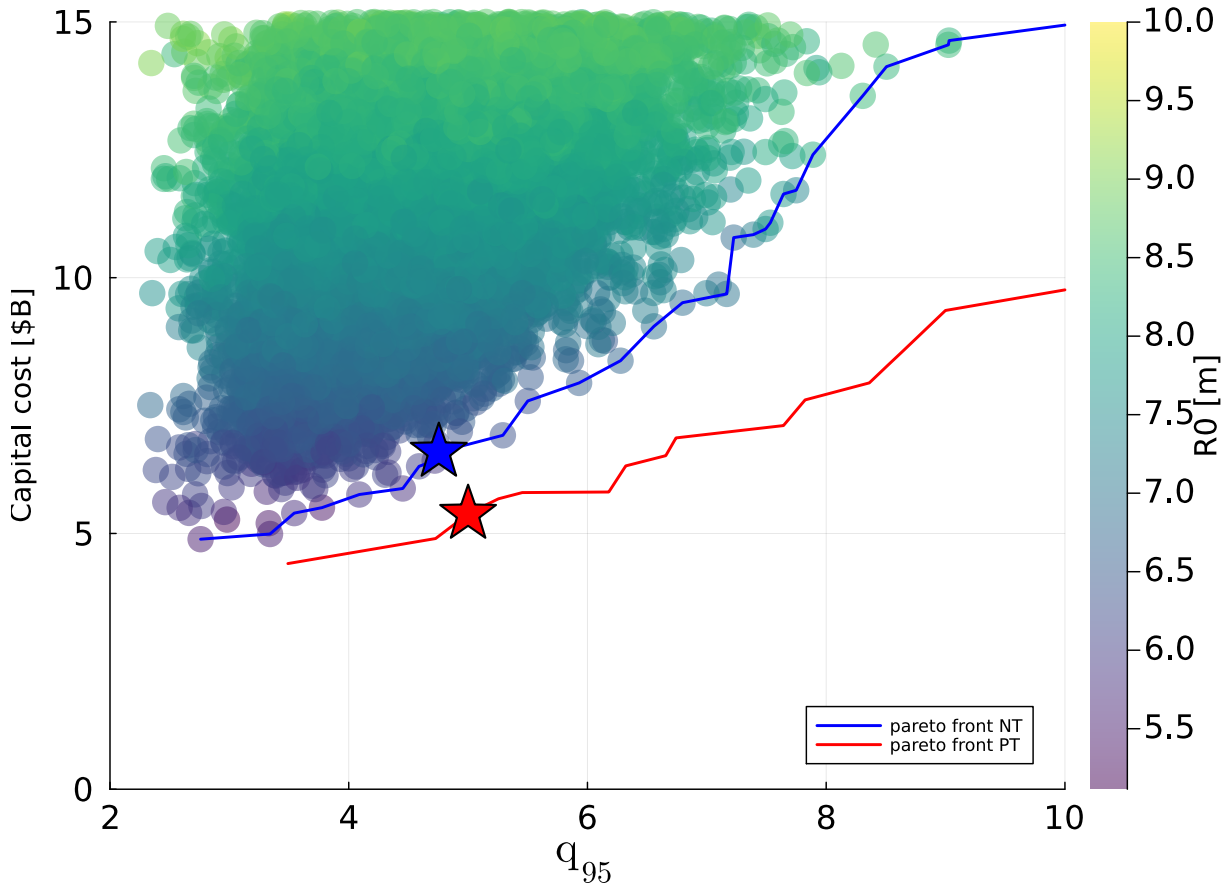


Comparing two cases with similar safety factor



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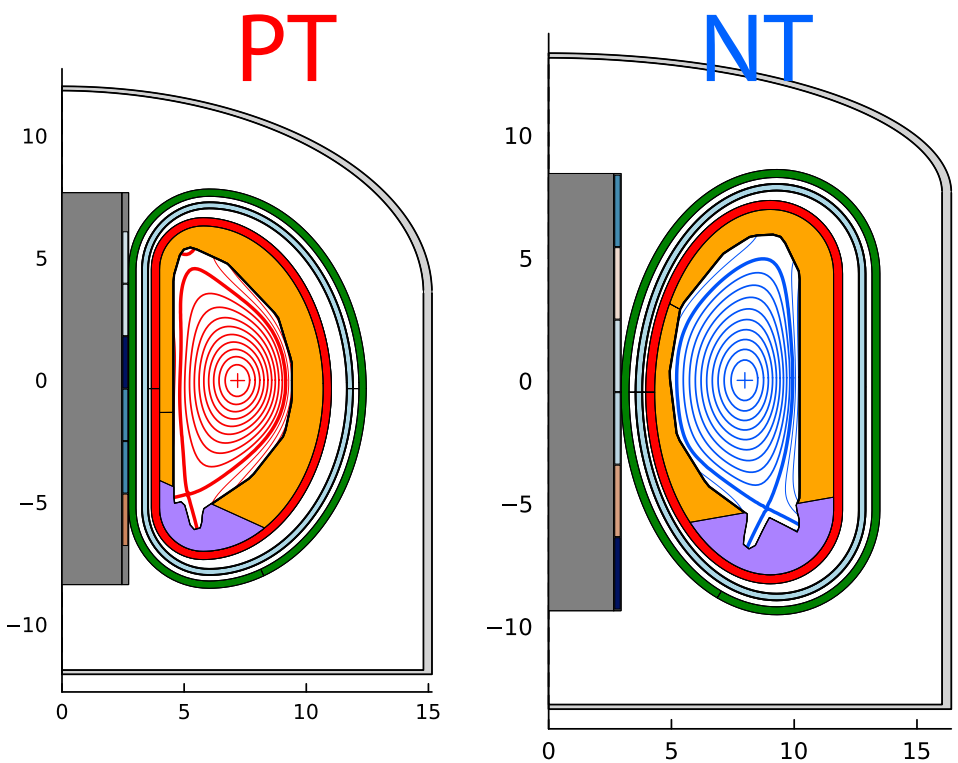
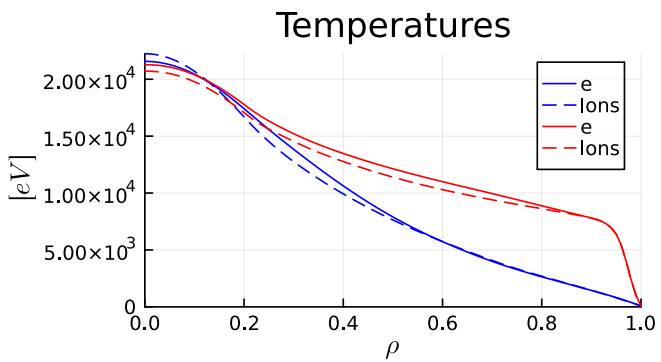
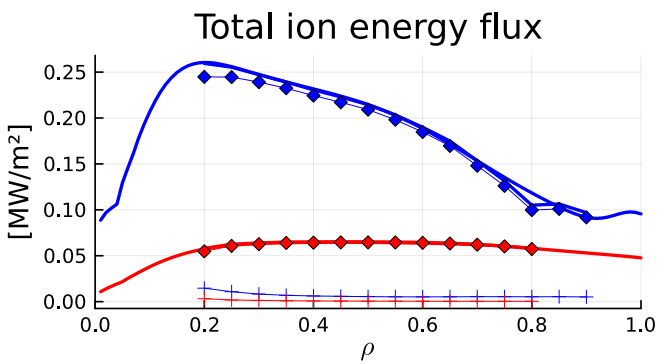
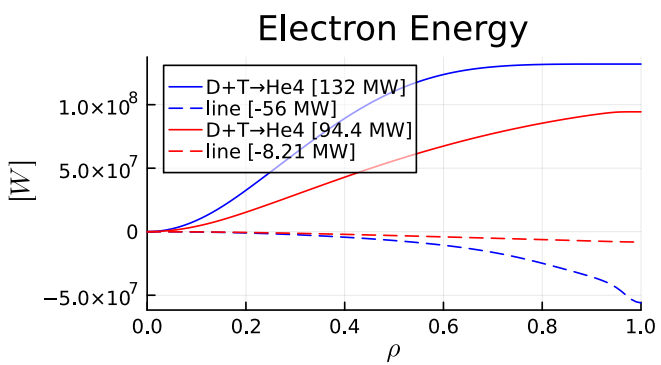
# PT and NT achieve similar net Pelectric but with quite different core solutions




| Parameter | PT | NT |
|---|---|---|
| $P_{\text{net elec}}$ (MW) | 233 | 263 |
| $P_{\alpha}$ (MW) | 121 | 166 |
| $P_{\text{rad}}$ (MW) | 41 | 122 |
| $f_{\text{gw}}$ | 0.7 | 1.1 |
| impurities | He-Ne | He-Ne |
| $P_{\text{sol}}/R$ (MW/m) | 15 | 15 |

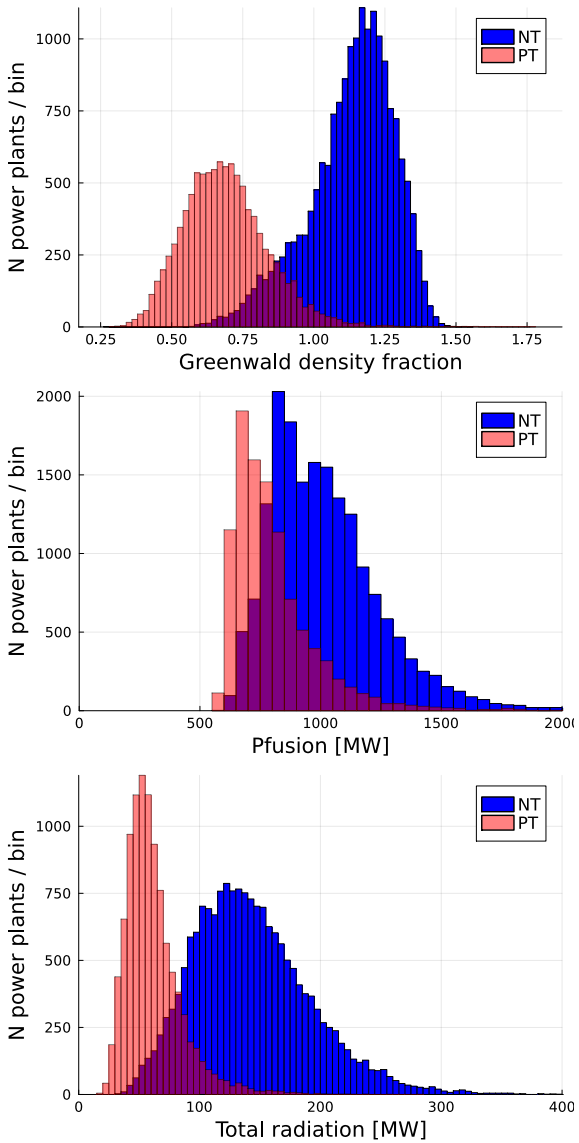


# PT operates at reduced fusion power to satisfy Psol/R. NT max performance is limited by edge radiation not Psol/R

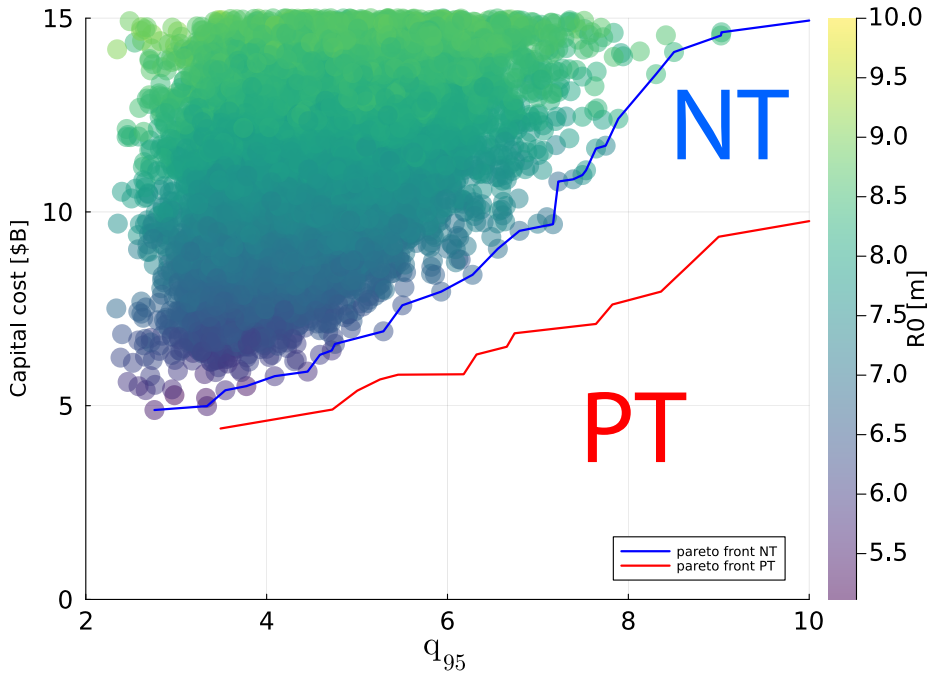
- **PT**
  - Psol/R $<$ 15 (MW/m) is the main limiting factor
  - Fusion output is lowered by operating at lower density to satisfy Psol/R
- **NT**
  - Must overcome higher (edge) radiation
  - Which limits the performance more than Psol/R



# Conclusion: NT retires core-edge integration risk, PT has potential for cheap power plants at increased operating risk

- PT has the potential for higher core performance
  - Could build smaller (cheaper) devices...
  - ...but detachment is a must to allow for higher Psol/R
- NT retires the core-edge integration risk
  - Easy core-edge integration and material choice (plus doesn't have ELMs or LH transitions to worry about)...
  - ...but size of the device set by the core physics

Next step :: add SOL modeling




Pareto curves:

- NT: Loss of confinement at higher q95 (lower Ip)
- PT: Psol/R limit