Consideration of ECH Modifications and Implication to ITER Steady State Scenarios

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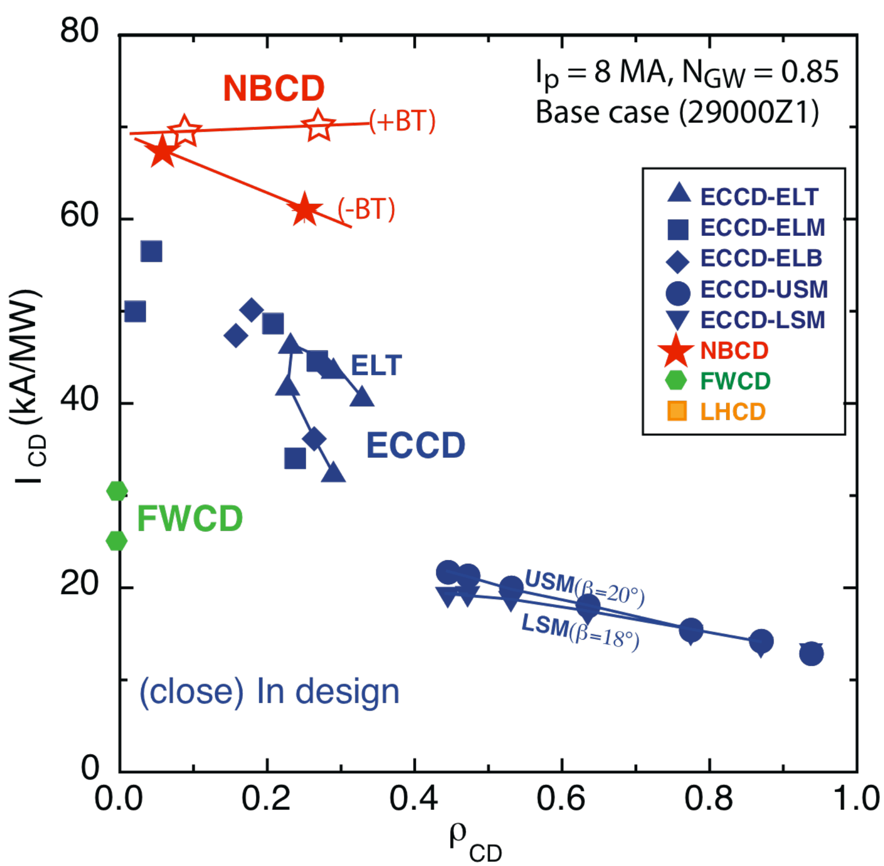
BACKGROUND / OUTLINE

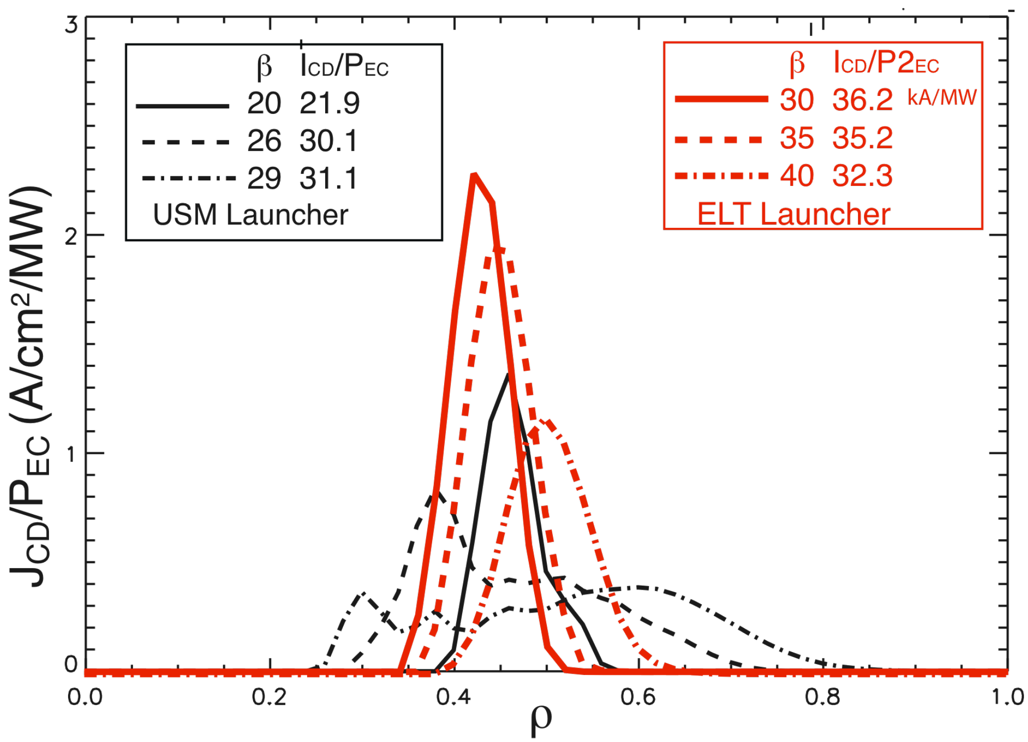
- **The last presentation (IOS TG at JET) on possible Upgrade of the Upper Launcher and its effects on SS scenarios**
- **Japanese ECH Team looking into Equatorial Launcher modifications allowing its poloidal steering**
  - Increase and broadened CD efficiency
- **Comparison between Effects of the Upper Launcher and Equatorial Launcher on steady state scenarios**
- **Steady State Exploration – benefit to the 9-MA scenarios**
  - CD comparison with 9-MA case
  - Optimization of the 9-MA scenario with ECH upgrade for simultaneous achievement of f_{NI}=100% and Q=5
    - USM + ELT upgrades
    - doubling the ECH power (40MW)

The ITER Day-1 H & CD Systems Had Some Gap In CD Coverage For Steady State Scenario Development



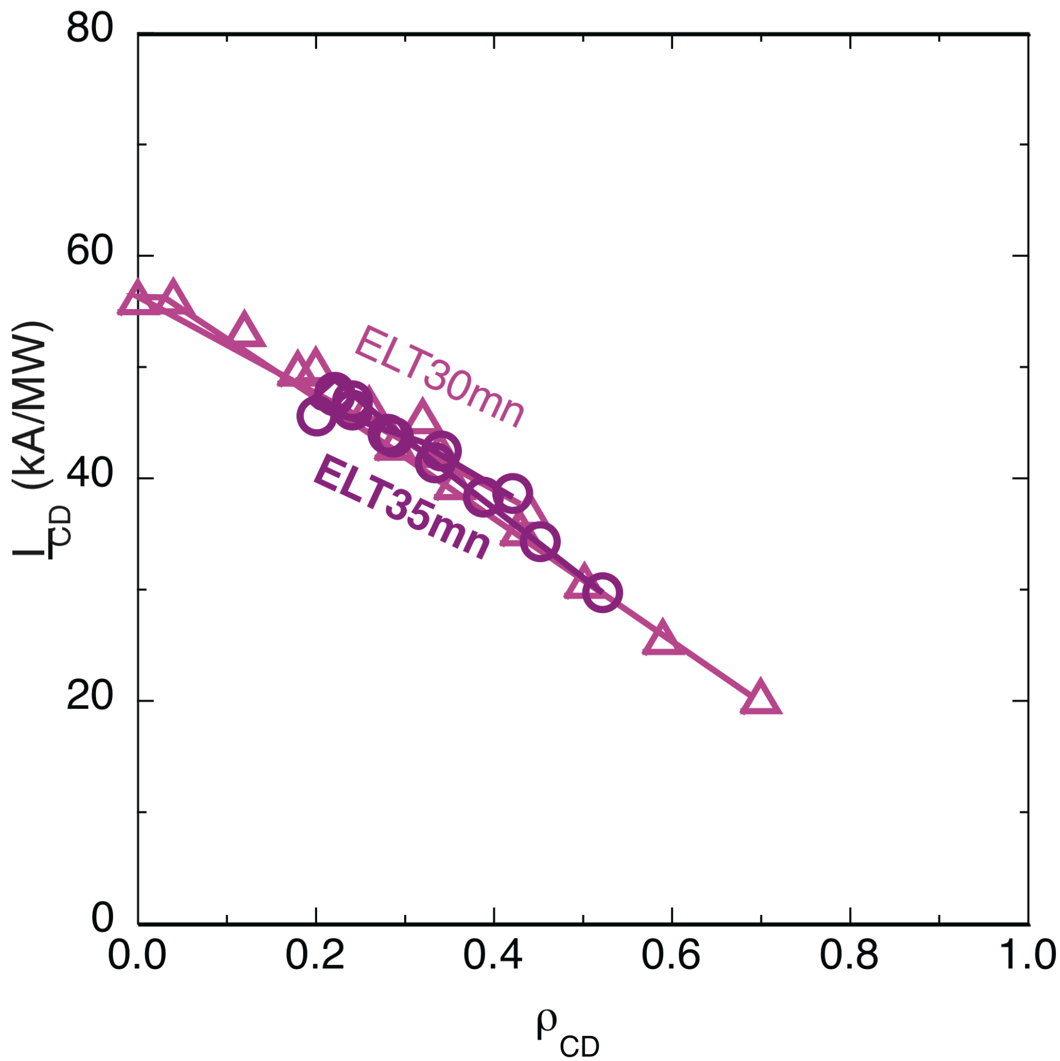
- **CD efficiency (kA/MW) for the ITER main H&CD sources for a fixed profiles (8-MA Baseline)**
- **The present H&CD capability shows a gap of CD at $\rho \approx 0.4$**
- **The upper launchers (and EQL) are optimized for NTM feedback control ➔ Narrow**
  - **Hopefully sufficient with LSM alone**
- **For current profile control needs**
  - **Broader CD profile preferred**
    - **Even possible for D; control of NTM**
  - **High efficiency**

CD Profiles Calculated increase broadening and integrated CD as alpha increases from 30 to 40 degrees



- The ECH/CD calculation using CQL3D/TORAY to take into account the electron momentum conservation
- For current profile control needs broadening
- Doppler effects in EQL are smaller than in USM, there is no big shoulder in H and CD profiles
- See R. Prater's presentation

Poloidal Angle Scams In EQL Launcher (A = -26 To 40 Degree) Covers Wide Radial Range (R = 0 To 0.7)

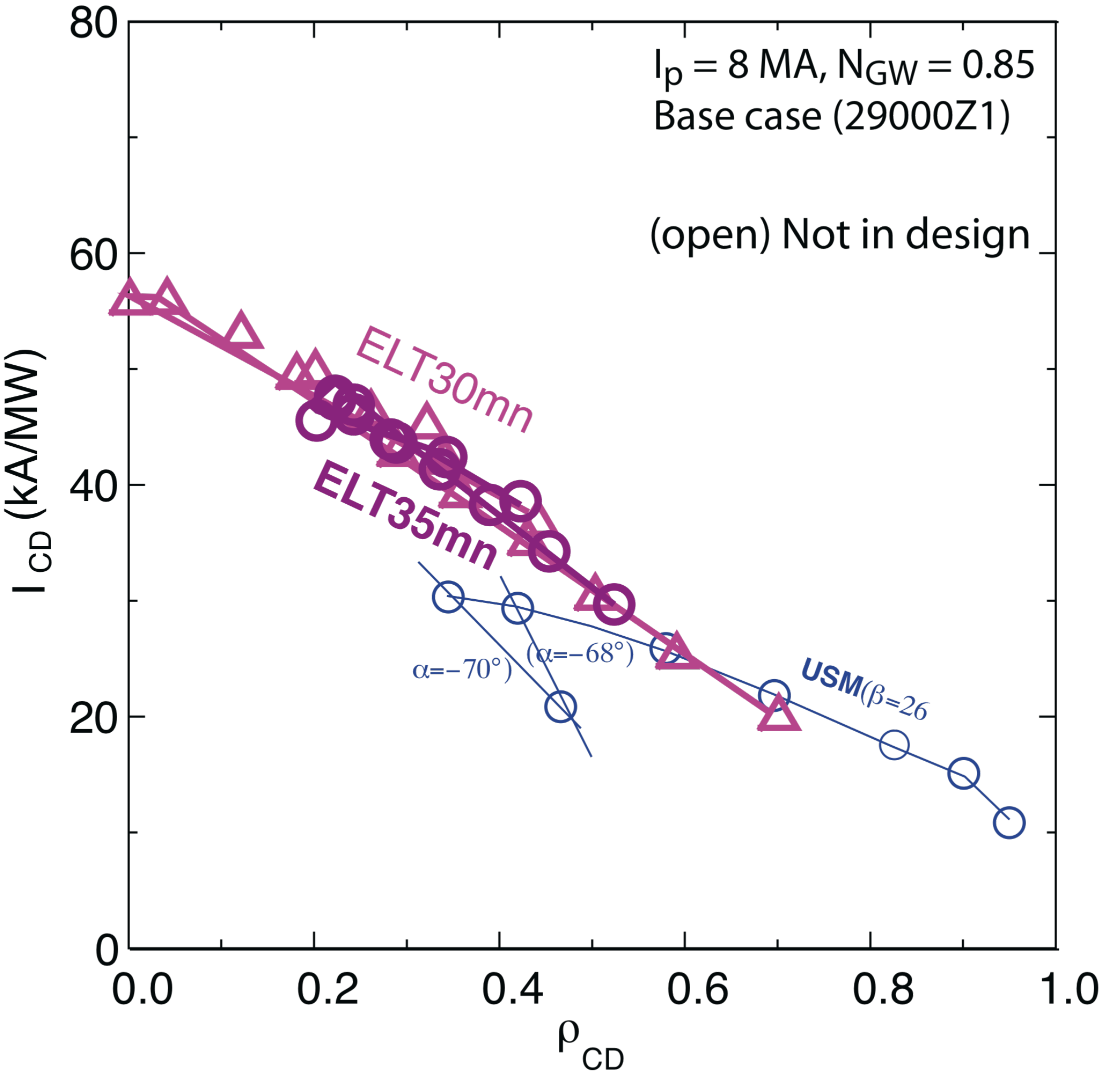


ELM30mn scan:
B = 30
A = +24 -> -40

ELM35mn scan
B=35
A= 24 -> -40

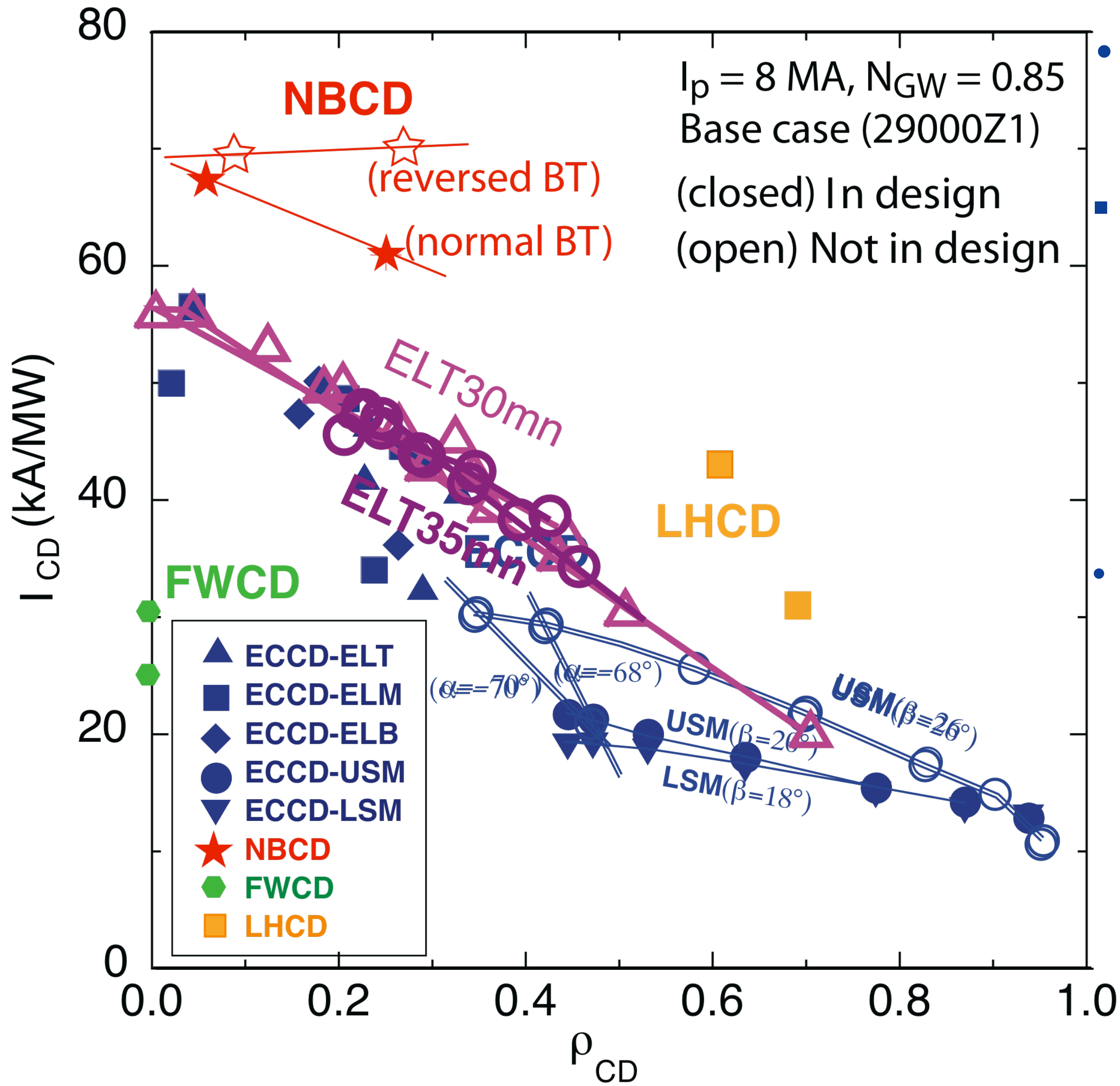
Increase beta decreases radial ranges but broadens current profiles

Combination of ELT and USM modifications should be able to cover the H&CD control capability in rho = 0 to 0.9



- See R. Prater's Culham presentation
- This ECH/CD calculation using CQL3D/TORAY to take into account the electron momentum conservation
- The (linear) decreases of CD efficiency in radius is due to increases in electron trapped particle fraction
  - Opposite to the NBCD case

ECCD upgrades increases very substantially ITER H&CD capability in the entire range of the plasma radius

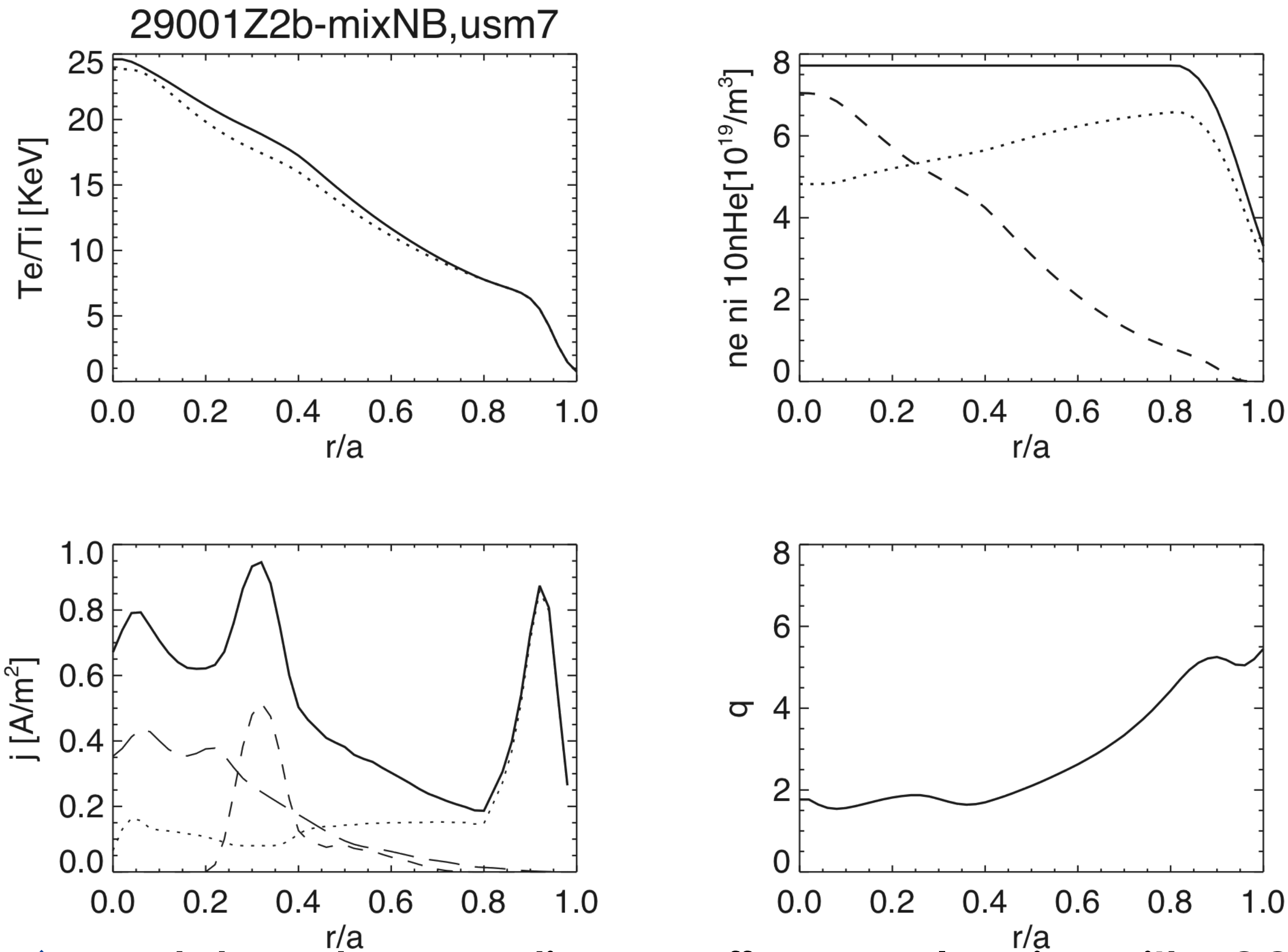


- **The Use of ECCD should not be limited to NTM control**
- **The previous UL design was optimized only for NTM feedback which requires narrow CD**
    - **Hopefully LSM18 system is sufficient for it**
- **Current profile control for SS operation needs**

OPTIMIZATION OF 9-MA SS SCENARIOS

- **NBI geometry : part of off-axis moved toward the axis**
- **Minimize ICRF power (except the seed current needed)**
- **ECH Upgrades:**
  1. Upper launcher to broaden off-axis peaking using USM26
  2. Consider $\leq$ 40-MW ECH system
- **Try to get simultaneous achievement of 100% f_{NI} and Q=5**

Optimization of 9-MA SS scenarios using the ECCD upgrades approaches close to the goal of Q=5 and f_{NI}=100%



NBI:
16.5MW on-axis
+ 16,5MW off-axis
No ICRF)
ECCD-40MW (upgrade)
Q=5.35
P_{DT} = 391MW
f_{NI} = 98%
f_{BS} = 63%
f_{NB} = 21%
f_{EC} = 14%
H_{98} = 1.44
N_{GW} = 0.90

- **Broad shear by spreading on+off NBI overlapping with ECCD:**
  - **— ELT30-6 (20 MW) + USM26-7 (20 MW)**

CONCLUSION

• Modifications of upper and Top EQ ECH launchers for current profile control was considered. Increase poloidal and toroidal angles leads to :

-- increasing CD by ~50% (calculated with CQL3D/TORAY)

-- filling in the previous gap between on axial CD (EQ Launchers and off-axis NBI) and the Upper launchers

• 9-MA SS scenarios with the ECH upgrade was examined using GLF23 with ITER-Demo edge conditions. Further exploration was in progress:

- The ECH upgrades
- Increase ECH power to 40MW (still keeping total external power of 73MW)
- use off-axis NBI and on-axis NBI (with varying steering angles)
- minimize ICRF power (except seed current needed)

• These explorations obtained full NI and $Q_{DT} \geq 5.6$ with smooth reverse sheer q(ρ) profile (q-min>15)