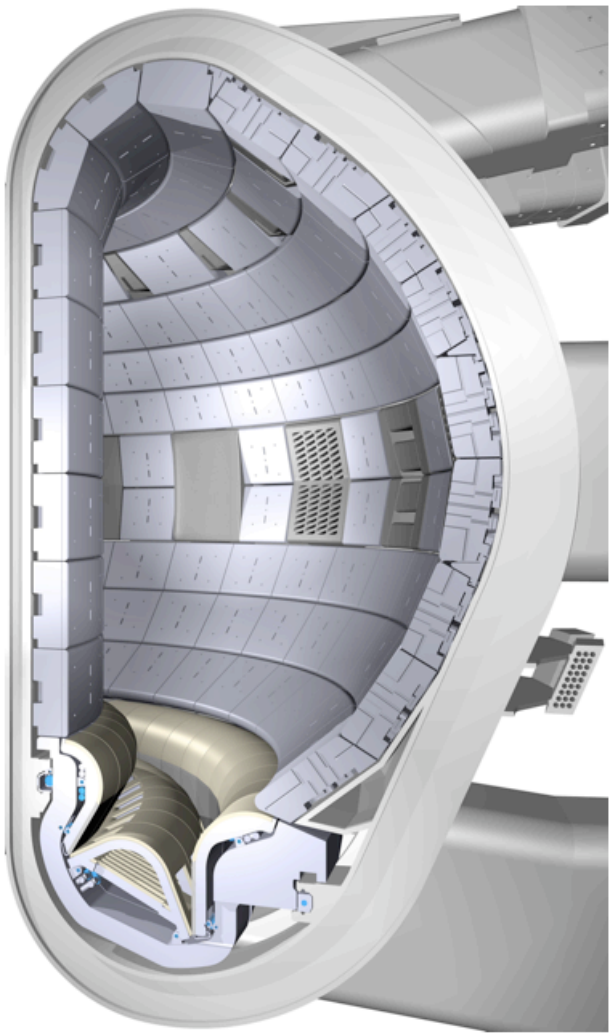
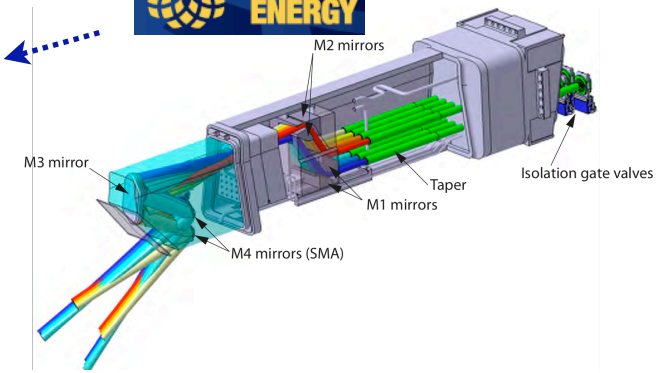
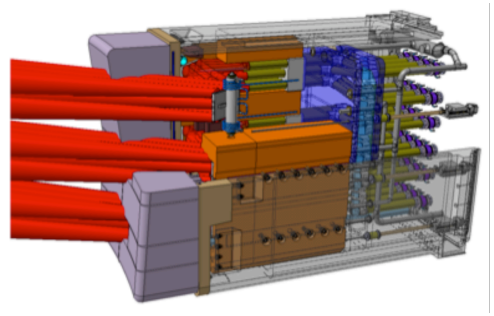
Optimization of the EC Launchers

Upper launcher

- 4 ports, 8 entries each
- Control of MHD activity (NTMs)







20MW

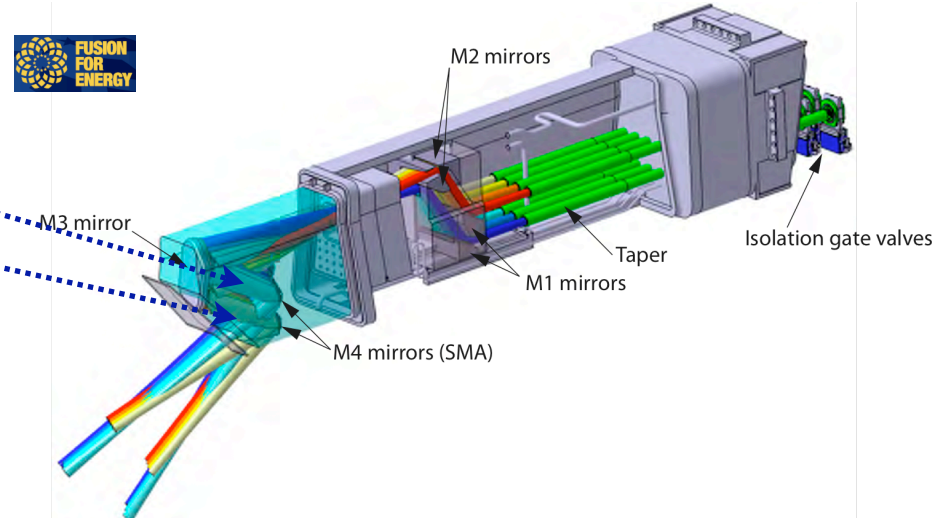
Equatorial launcher:

- 1 Port, 24 entries
- Central heating and current drive

Upper Launcher Beam Characterization

The 8 Beams from the UL

- Two steering mirrors each directing 4 beams
- USM (upper steering mirror): $0.3 \leq \rho_T < 0.8$
- LSM (lower steering mirror): $0.6 \leq \rho_T < 0.95$
- Poloidal steering with fixed toroidal angle (18 to 20˚)
- four beams orientated to have overlap in plasma (small divergence in toroidal direction)
- divergence depends on launch point of four beams (changed in 2009)



General Characteristics (preliminary)

- wm = 50mm
- USM: w_0 = 29mm (17.4mm) in Pol. (Tor.)
- LSM: w_0 = 21mm (21mm) in Pol. (Tor.)
- USM: (R, Z) = (6770.3, 4388.7) {center of four beams)
- LSM: (R, Z) = (6869.3, 4194.0) {center of four beams)

Optical Study continues in 2011...

Optimization of the ITER UL

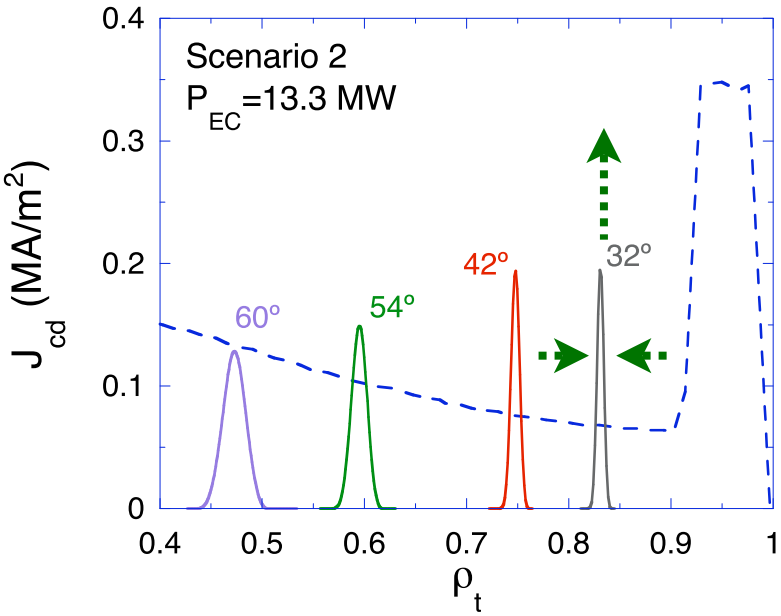
Guidelines for UL are straight forward: narrow peaked j_{CD} (≥1.2x j_{BS})

Optimization has included modeling analysis of:

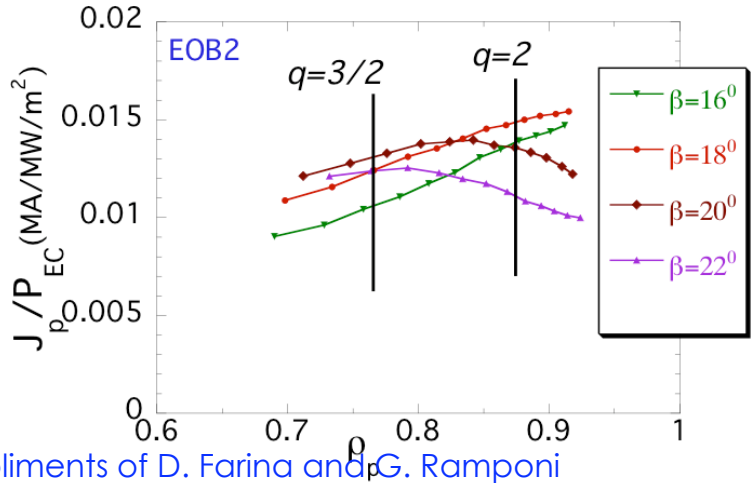
- Toroidal injection angle (see below)
- Poloidal steering range
- Waist size and location
- beam astigmatism
- relative beam spreading (four beams per mirror)

objectives:

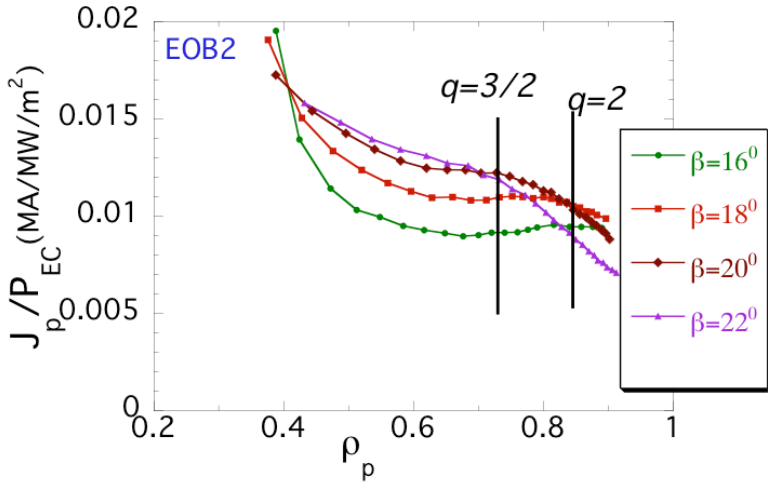
- increase j_{CD} and decrease w_{CD} ($w_{CD} \approx w_{marg}$)



β=18⁰ for LSM



β=20⁰ for USM



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UL Results:

EC Power required for $\eta_{NTM} > 1.2$

- q=2: ~6MW ≤ P_{EC} ≤ ~14MW
- q=3/2: ~9MW ≤ P_{EC} ≤ ~14MW
- Note that P_{EC} ≤ 20MW

Power modulation is also possible:

- 0 to 1kHz: ΔP_{EC} = 100%
- 1 to 5kHz: ΔP_{EC} = 50%

q=2

Scenario	SM	β	α	η_{NTM}	w_{cd}	MW for η_{NTM}=1.2
					(cm)	
Eob3	USM	20	54.5	1.61	4.5	9.9
	LSM	18	48.8	2.02	3.0	7.9
Eob2	USM	20	48.2	1.91	4.1	8.3
	LSM	18	41.4	***2.80***	2.4	***5.7***
Eob5	USM	20	43.5	***1.12***	3.7	***14.2***
	LSM	18	36	1.75	2.0	9.1

q=3/2

Scenario	SM	β	α	η_{NTM}	w_{cd}	MW for η_{NTM} =1.2
					(cm)	
Eob3	USM	20	60.2	1.31	5.6	12.3
	LSM	18	56.2	1.27	4.8	12.6
Eob2	USM	20	57.2	1.71	5.1	9.3
	LSM	18	52	***1.78***	3.8	***8.9***
Eob5	USM	20	53	***1.17***	4.2	***13.6***
	LSM	18	47	1.39	2.8	11.5

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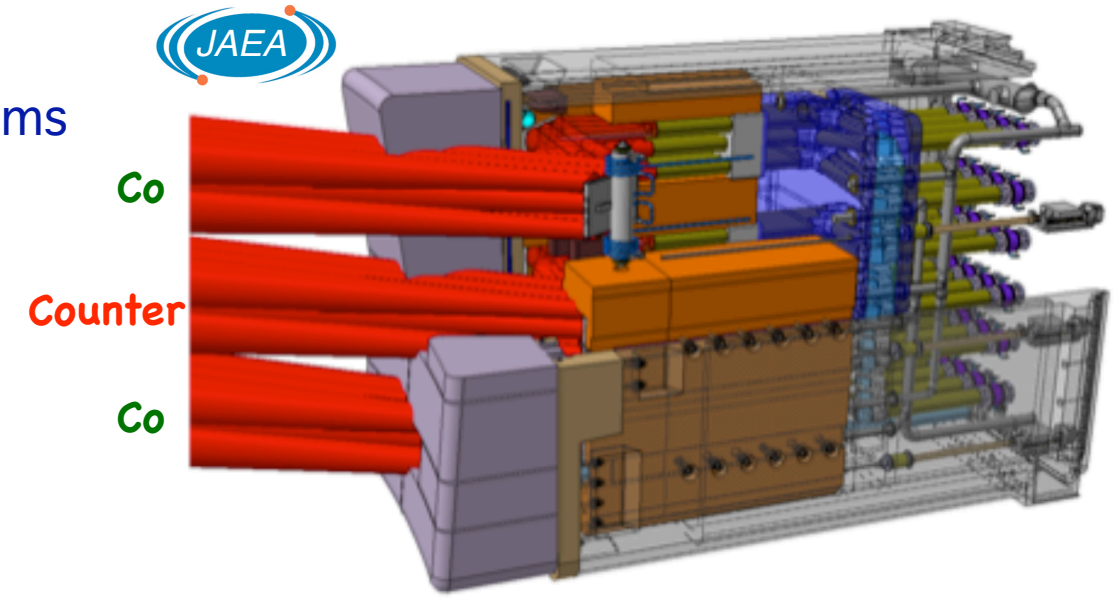
Equatorial Launcher Beam Characterization

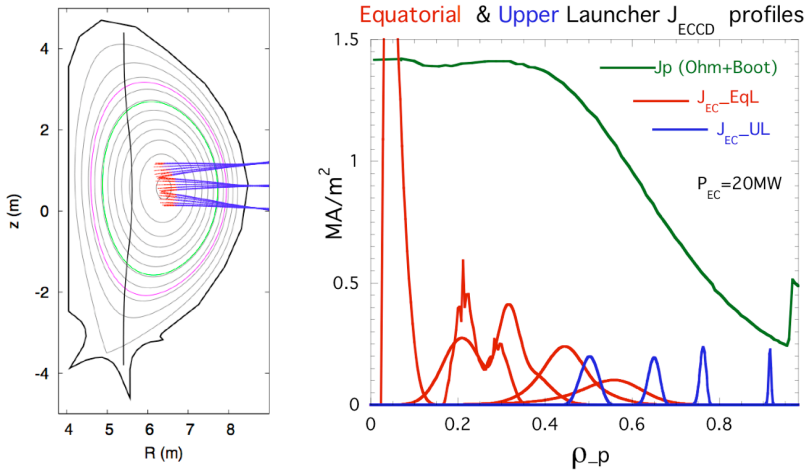
The 24 Beams from the UL

- Three steering mirrors each with 8 beams
- toroidal steering (20 to 41˚)
- Small poloidal tilt (±5˚) in top and bottom rows
- Top: co-ECCD $0.15 \leq \rho_T < 0.45$
- Middle: cnt-ECCD $0.0 \leq \rho_T < 0.45$
- Bottom: co-ECCD $0.05 \leq \rho_T < 0.45$
- each beam injected with different tilt angle



2007 Model

- Beams near parallel
- Propagate beams in far field
- Model as single beam
- w_0(tor) = 10.19mm at -690mm (behind mirror)
- w_0(pol) = 40.4mm at -6780mm (behind mirror)
- single beam simplifies modeling of 8 beams



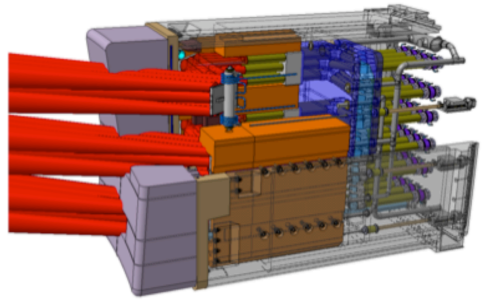
Profile of 'beams' at different steering angles

What profile is optimum for off axis ECCD

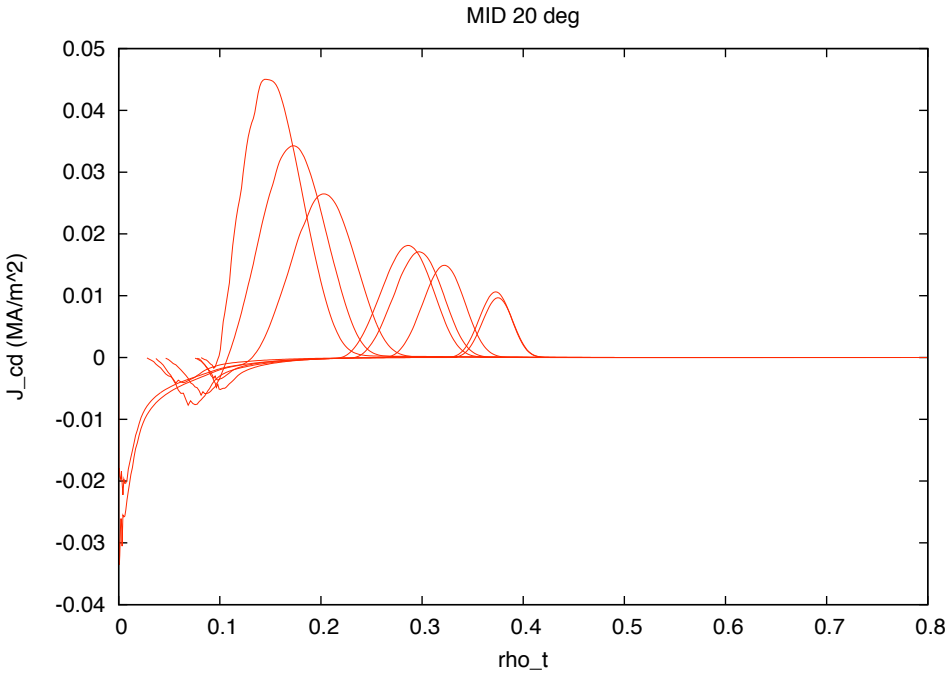
2010 Model

- Orientate beams to minimize BSM opening
- Neutron streaming level too high for EL
- Beams have ~±9° divergence angle

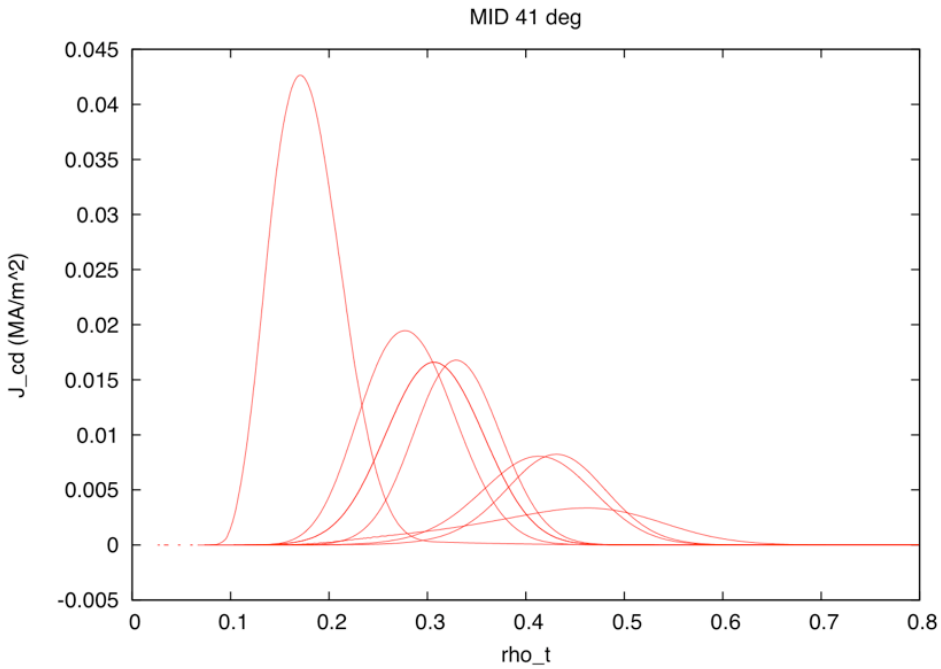
Minimize BSM opening results in large spread



8 beams at 20° toroidal injection angle



8 beams at 41° toroidal injection angle



JAEA working toward tighter beam assembly, with same BSM opening

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