Calculations of Fast Ion Confinement on NSTX

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Motivation

Low magnetic fields in spherical torus
=>large Larmor radii.

How well confined are neutral beams?

OUTLINE

1. Characteristics of the NSTX
2. Three codes to assess fast ion confinement in NSTX
   Comparison of CONBEAM, EIGOL, GYROXY
3. Conclusions and future work

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II. Methods to Calculate Collisionless Fast Ion Loss

CONBEAM: Orbit topology approach
with Larmor radius correction
J. Egedal, PSFC, MIT

EIGOL: Lorentz code; full Larmor radius code
integrates orbits in (Z,R)
D. Darrow, et al., EPS, Madeira, Portugal, 2001

GYROXY: Fast, similar method to EIGOL
R. B. White, Phys. Plas. (2002)

All include RF limiters
for careful treatment of loss conditions

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Collisionless Fast Ion Loss: NSTX Equilibria

CONBEAM

For NSTX equilibria $0.6<I_p<1$MA, $0.3<B_T<0.45$ T,
losses of 10% to 50%;
best confinement at high I_p, B_T and small ρ_L.

GYROXY and EIGOL

NSTX 23% β equilibrium

Benchmarked for an 80 KeV, 0.5 m tangency radius beam
Excellent agreement at short times:
21% of 54,000 ions lost after ~7.5×10^5 sec.

GYROXY: After x10 longer orbit time ($\tau_{slow}/20$), 26% loss

CONBEAM: 26% loss

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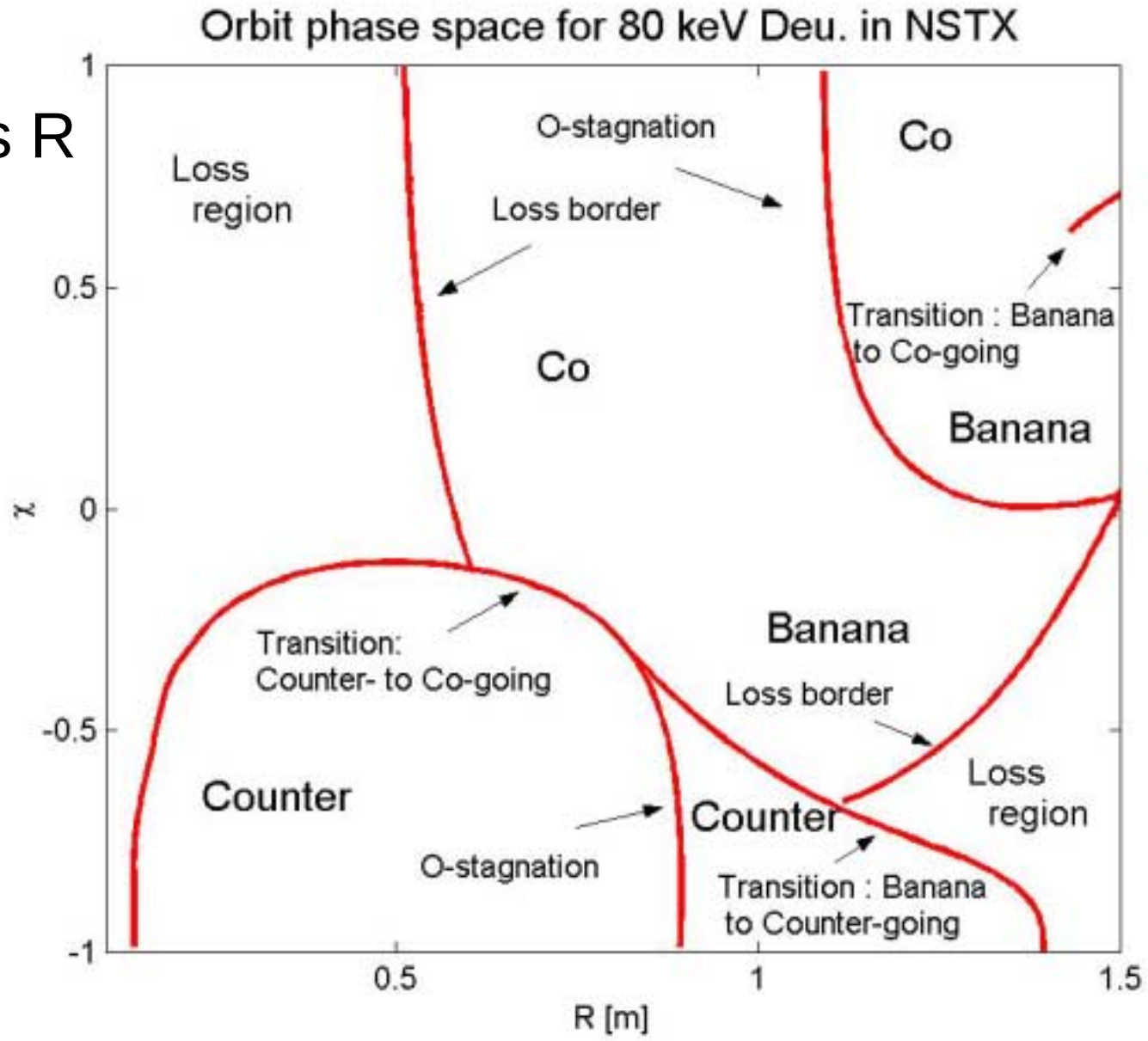
CONBEAM: Orbit Topology Code (Egedal)

$\chi = v_{//}/v$ vs R

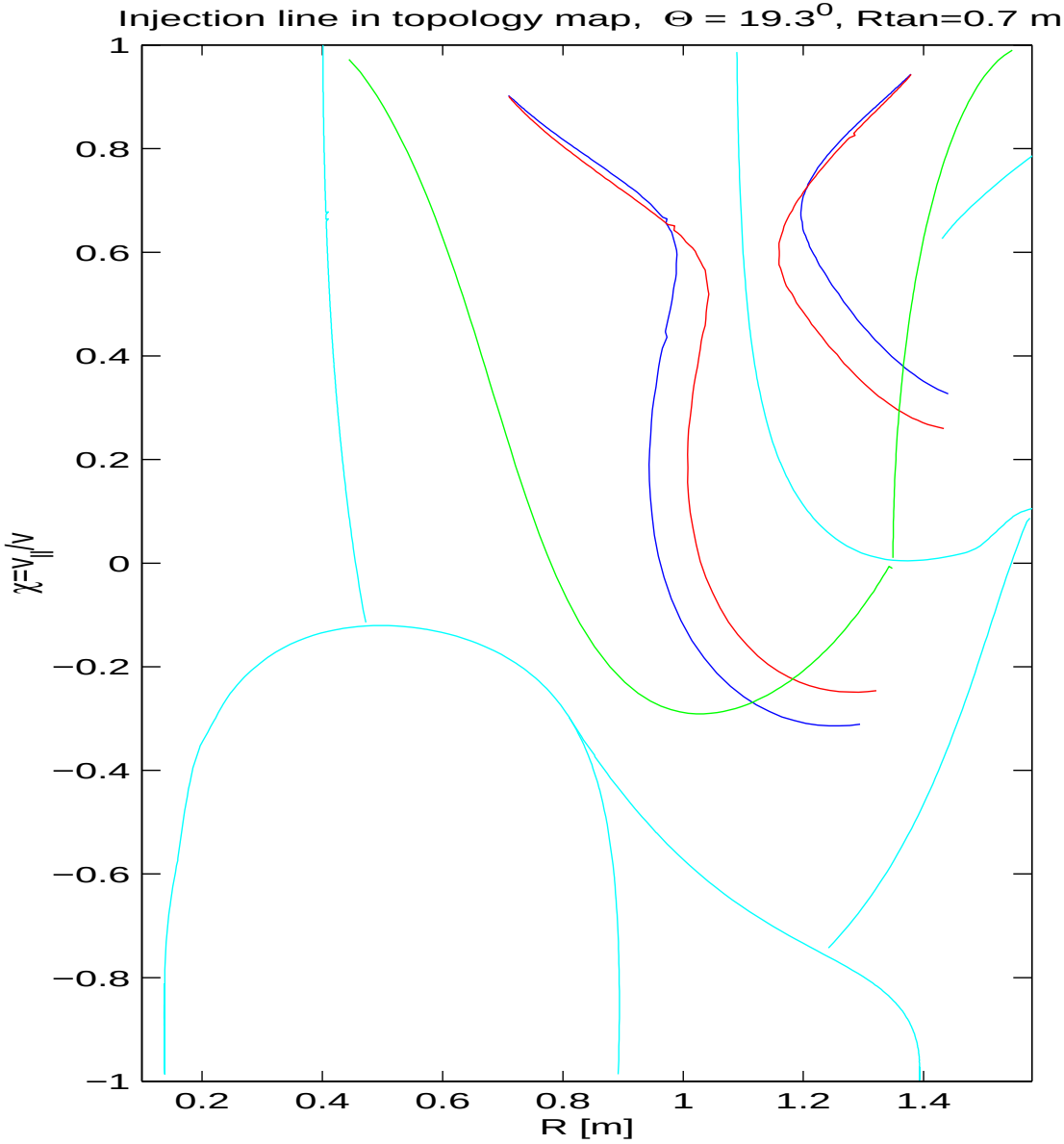


CONBEAM: Orbit Topology Code (Egedal)

Turquoise:
Boundaries of lost
and confined orbits
of guiding centers

Green:
Boundaries of
confined orbits
for full larmor radius
beam ions

Red and Blue:
for both orbit
legs of inward and
outward going
injected beams



CONBEAM: Results for 15 NSTX plasma equilibria

Shot id	I_p(MA)	κ	B_t(T)	Limiter ρ_L	Confinement fraction at tangency		
					0.5m	0.6m	0.7m
23% beta	1.0	1.7	0.34	0.2309	0.7418	0.7700	0.7779
104370	1.0	1.7	0.35	0.2333	0.7660	0.7759	0.7817
104282	1.0	2.0	0.30	0.2806	0.7333	0.7445	0.7516
102442	0.8	2.0	0.30	0.2927	0.7142	0.7326	0.7401
103275	0.6	1.7	0.30	0.2794	0.6408	0.7315	0.7412
106382	1.0	1.6	0.34	0.2098	0.7768	0.7897	0.7937
106382(c)	1.0	1.8	0.34	0.2000	0.7319	0.7375	0.7378
104391	0.8	1.7	0.30	0.2691	0.7373	0.7489	0.7558
104879	1.0	1.7	0.30	0.2592	0.7503	0.7600	0.7653
105542	0.8	1.7	0.45	0.2044	0.7386	0.7806	0.7853
105572	1.0	1.7	0.45	0.1989	0.7732	0.7873	0.7913
105582	0.8	2.0	0.45	0.2192	0.7409	0.7739	0.7762
105631	0.6	2.0	0.45	0.2264	0.6362	0.7611	0.7641
105632	0.6	1.7	0.45	0.2091	0.6447	0.7685	0.7747
105645	0.6	2.0	0.30	0.3054	0.4780	0.6833	0.7143
105917	1.0	2.0	0.45	0.2051	0.7473	0.7823	0.7866

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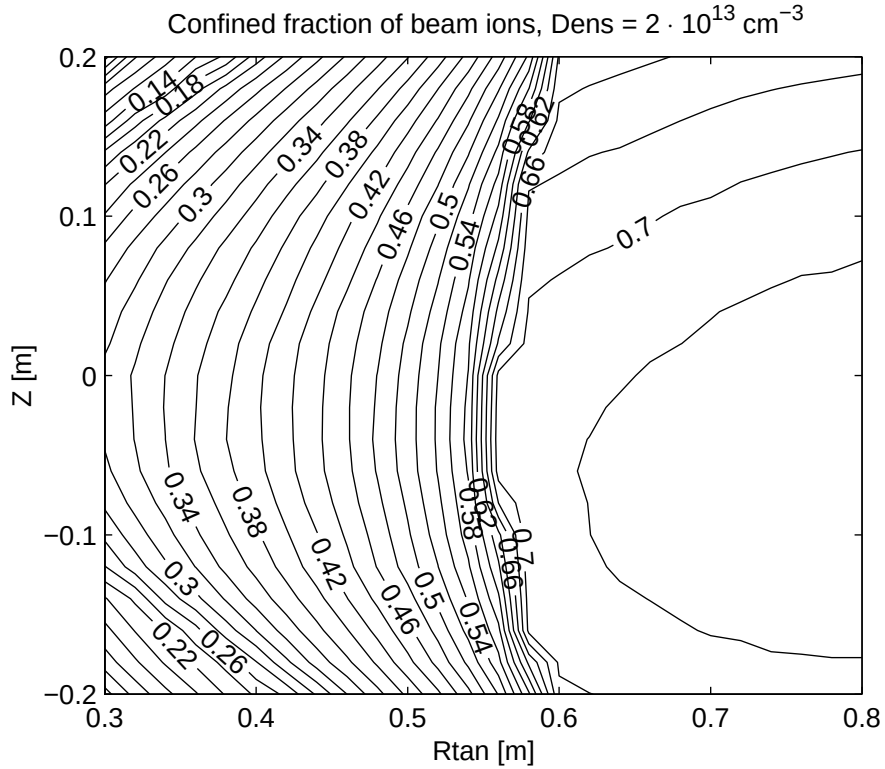
CONBEAM: Confined fraction for low current NSTX plasma

Shot 105645

IP=0.6

Bt=0.3T

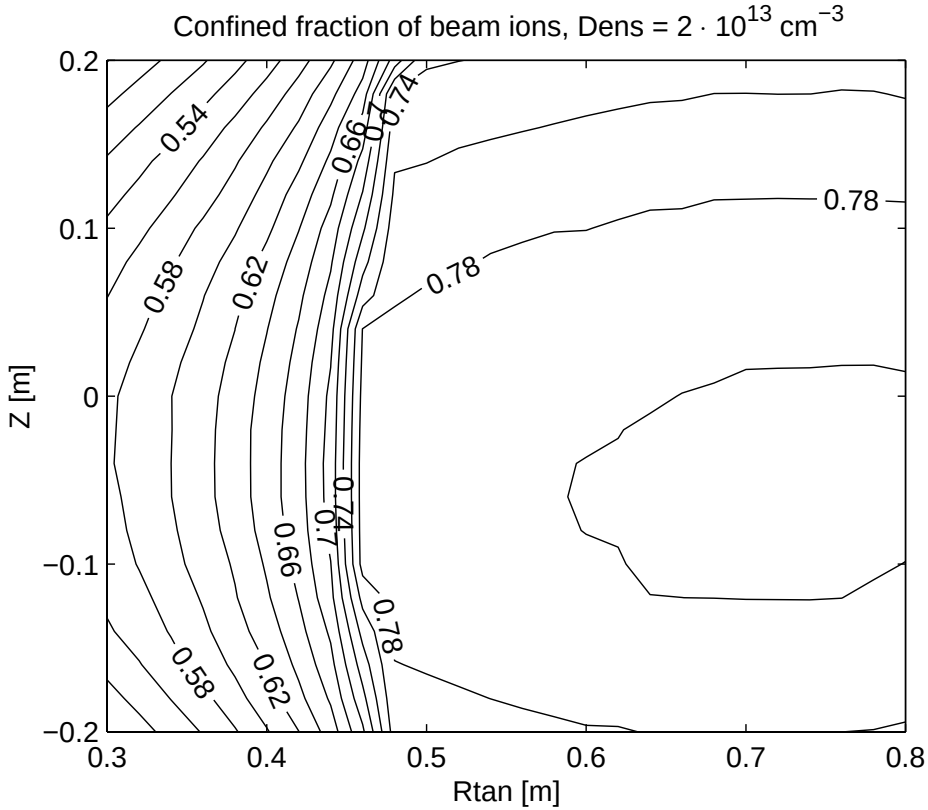


CONBEAM: Confined beam fraction for high current NSTX plasma

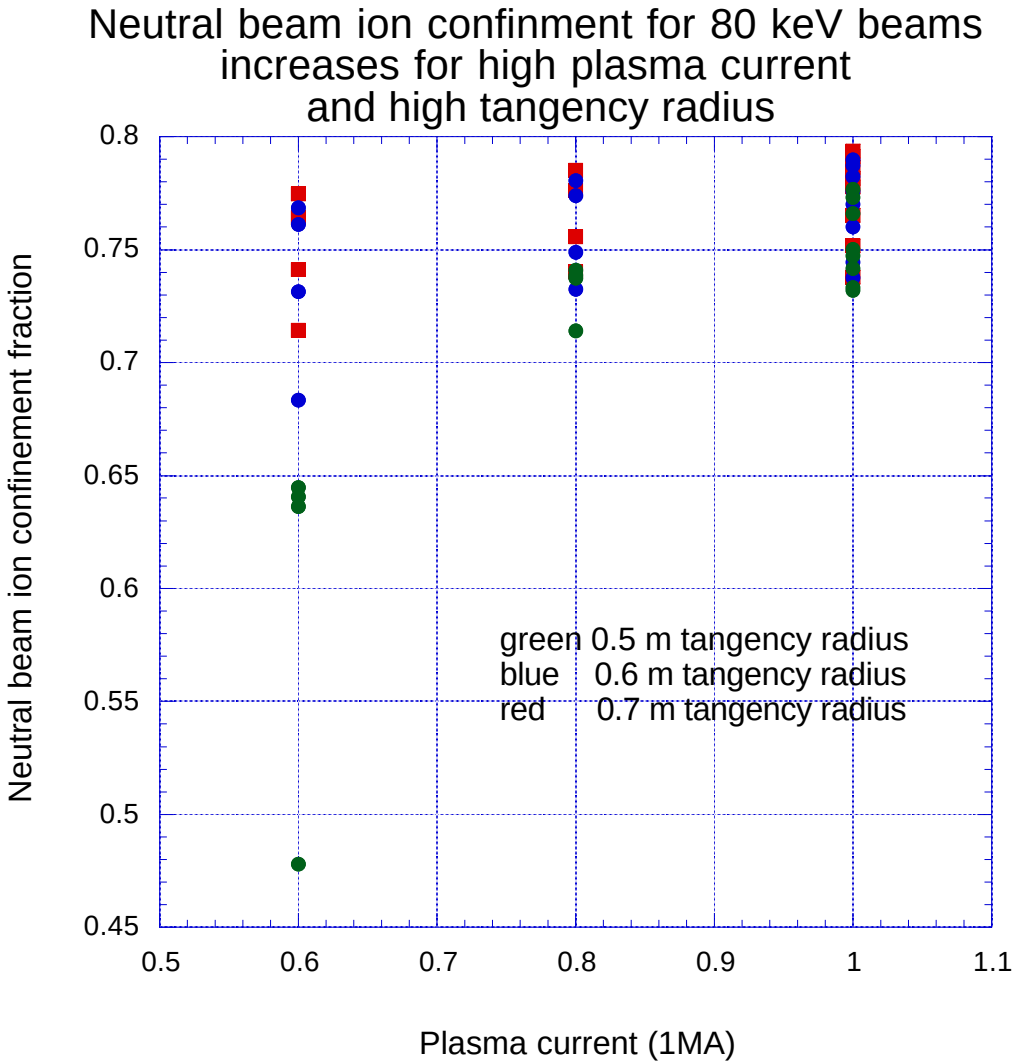
Shot 105572

IP=1.0

Bt=0.45T



CONBEAM: High current increases fast ion confinement



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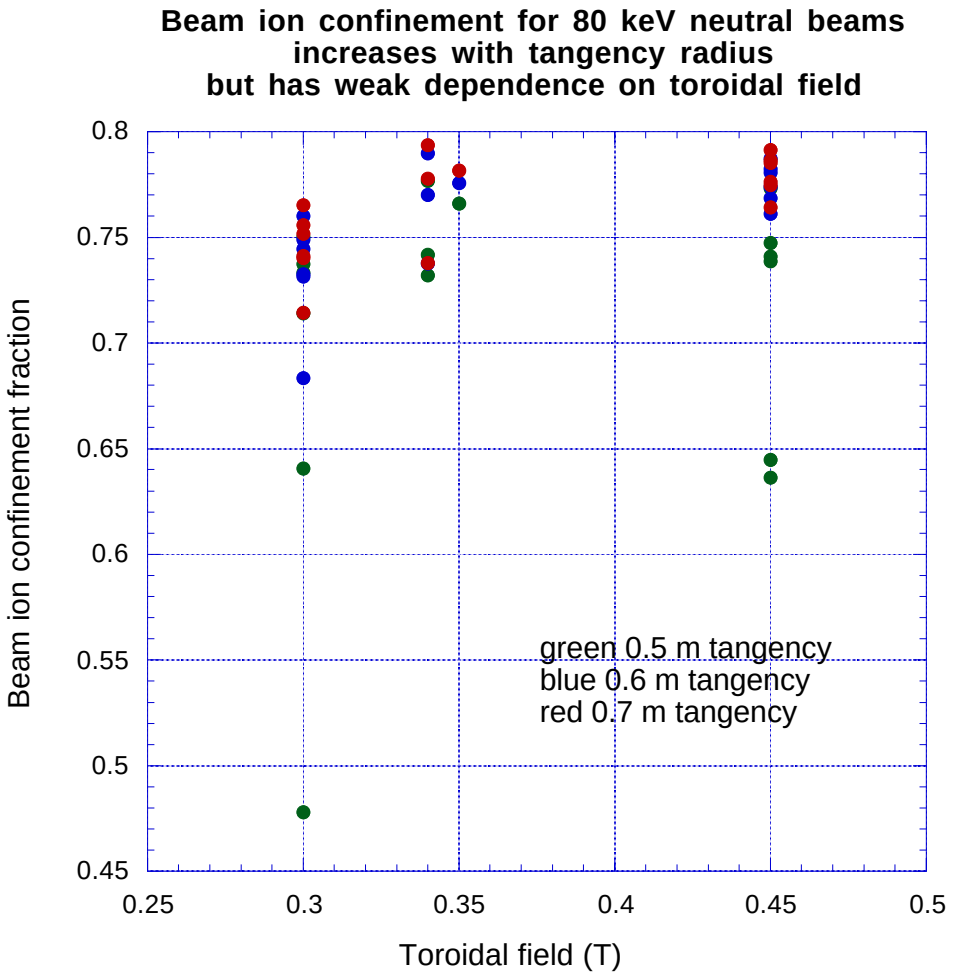
CONBEAM: Some improvement of fast ion confinement with high toroidal field, for larger tangency radius



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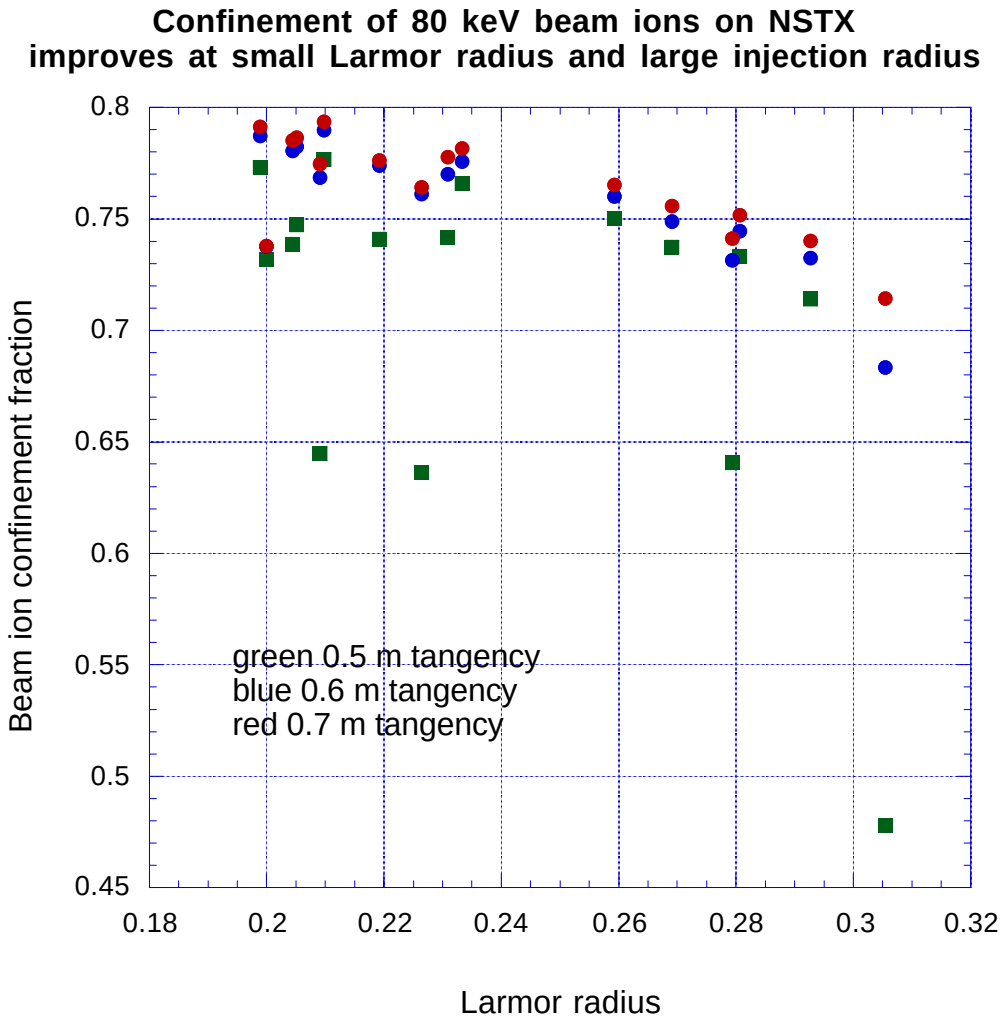
CONBEAM: Best fast ion confinement at small Larmor radius



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Conclusions

- Benchmarking of EIGOL and GYROXY
  confirms results of both codes and
  are in good agreement with CONBEAM - can extend GYROXY
  to long time orbit calculations

- CONBEAM provides fast estimates of confinement
  without details of ion orbit paths (minutes).
  Confirmed good confinement with high I_p, B_t, $1/\rho_L$, high r_{tan}
  15 EFIT NSTX equilibria : ρ_L best guarantor of good confinement
  A possible between-shots analysis code
  Recently upgraded to calculate nonadiabatic losses (small)

- GYROXY calculations
  - long integration time calculations of collisionless confinement (days)
  - can address nonadiabatic and collisional losses

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