ENERGY CONFINEMENT IN THE SPHERICAL TOKAMAK GLOBUS-M2 WITH A TOROIDAL MAGNETIC FIELD APPROACHING 0.8 T

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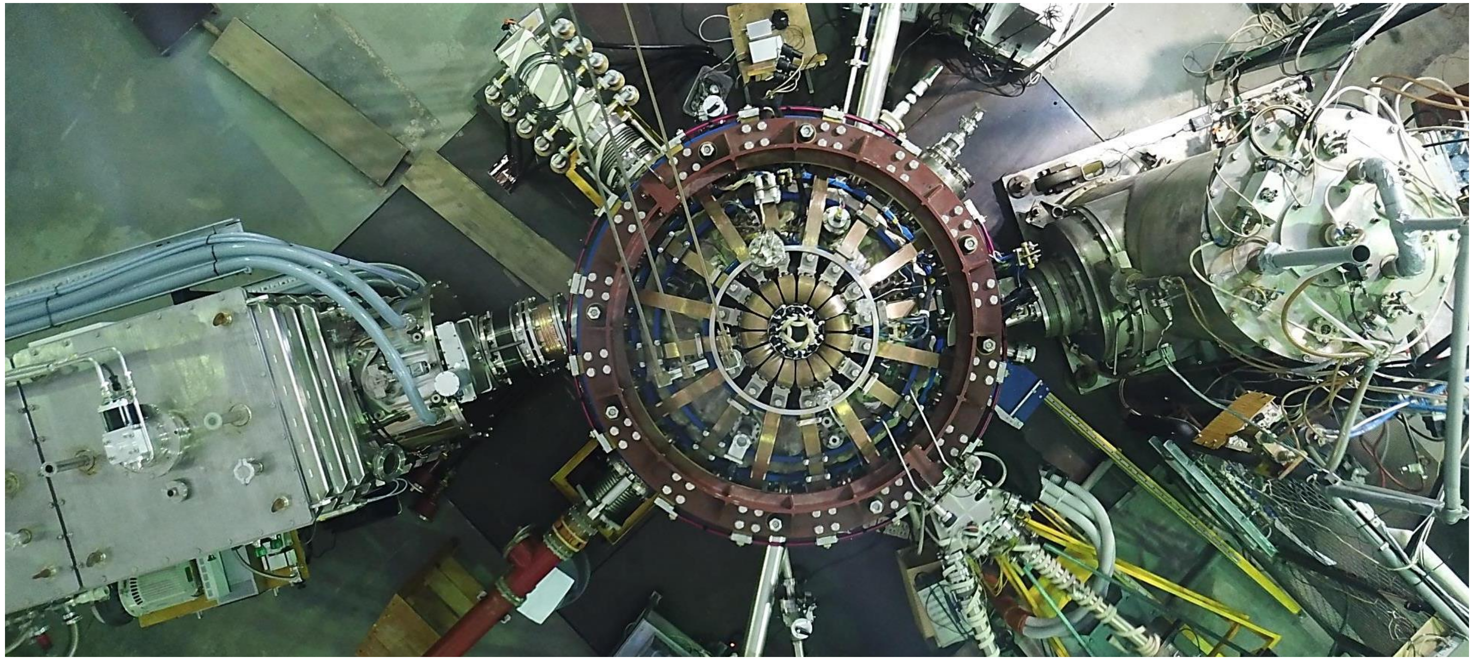
Spherical tokamak Globus-M2

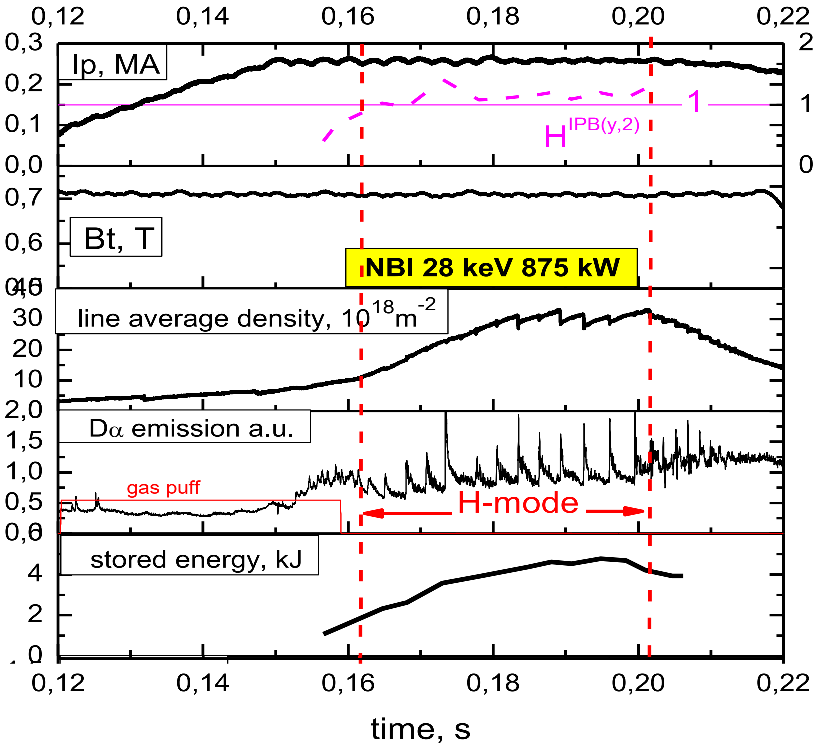


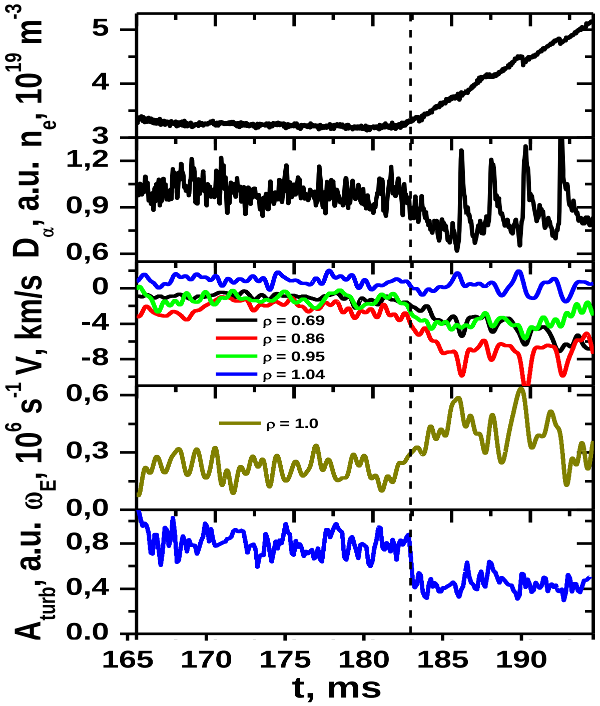
- **R [cm]/a [cm]= 36/24 = 1.5**
- **B_T = 1T, I_p = 500 kA**
- **Diverse diagnostics, heating and CD systems, including 2xNBI, ICRH, LHCD, plasma gun**
- **Extreme P_{heat}/V = 6 MW/m^3**

Parameter	Globus-M	Globus-M2
Btor/Ip, T/kA	0.4 / 250	**1 / 500**
NBI	1 MW 30 keV	**1 MW 40 keV + 1 MW 50 keV**
ICRH, kW	120	500
LHCD, kW	100	500

First plasma: April 23rd 2018

L-H transition at the Globus-M2





$P_{thr} = 0.072 \cdot n_{20}^{0.7} \cdot B_T^{0.7} \cdot S^{0.9} \cdot (Z_{eff}/2)^{0.7} \cdot F(A)^{0.5}$ *[ITPA 2004]*

$P_{thr}^{\ Globus\text{-}M2}$ = 0.08-0.1 MW, that is 4-8 times lower than the value of the loss power before transition

- A transition to the H-mode usually occurs a few milliseconds after injection of NB (E_b = 28 keV, P_{NBI} = 0.8 MW)
- The increase of the poloidal rotation velocity and the appearance of the ***ExB*** drift velocity shear near the LCFS was registered by DBS
- A sharp drop of the scattering density fluctuations amplitude is clearly observed during the transition
- The scaling for the ion heat flux is better suited for LH transition prediction for Globus-M2 plasma than the scaling for the total loss power

$$Q_{i,L-H} = 0.0029 \cdot n_{19}^{1.05} \cdot B_T^{0.68} \cdot S^{0.93}$$

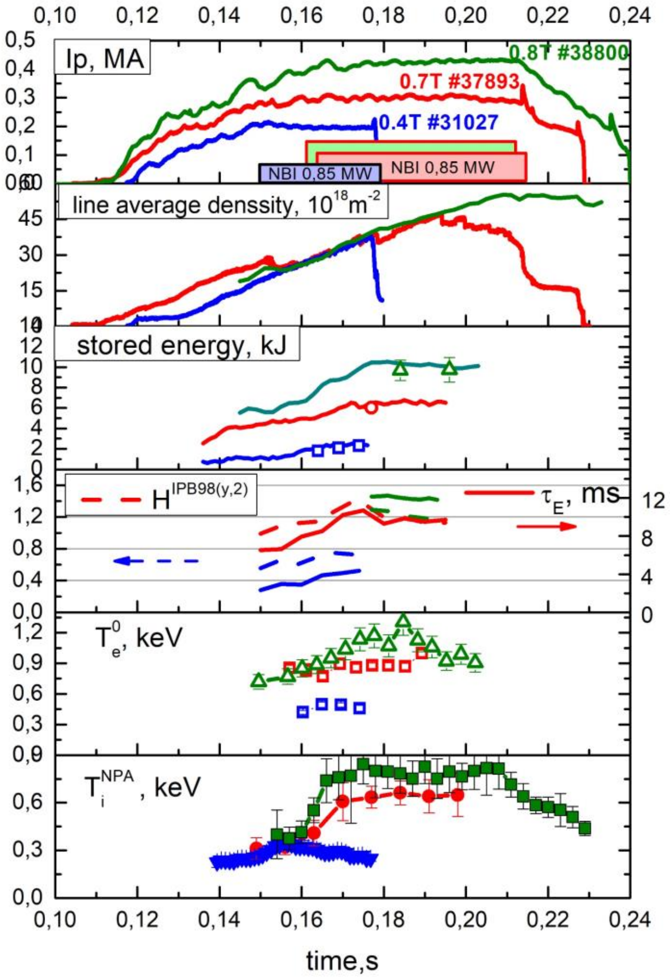
[Schmidtmayr 2018]

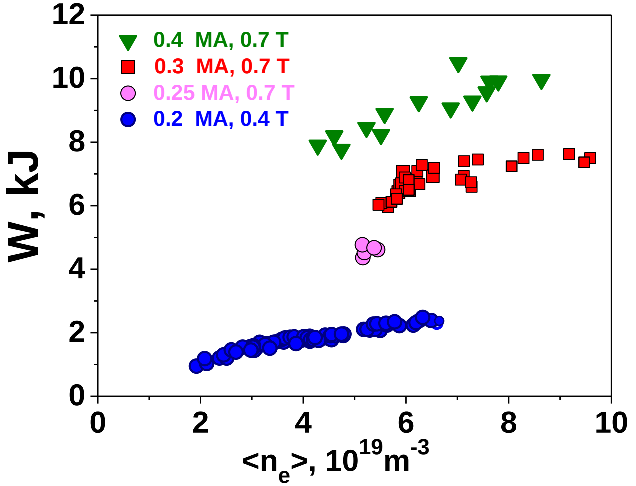
[Ryter 2014]

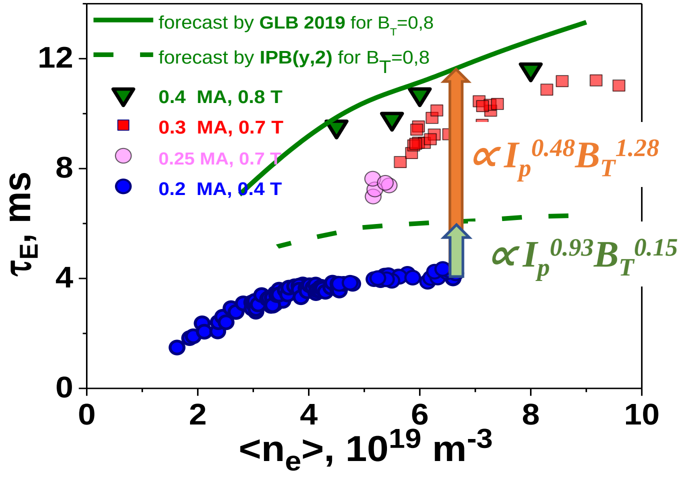
$Q_{i,L-H}^{\ scaling}$ = 10 - 15 kW

$Q_{i,L-H}^{\ ASTRA}$ = 15 - 30 kW

B_T impact on plasma performance in Globus-M2

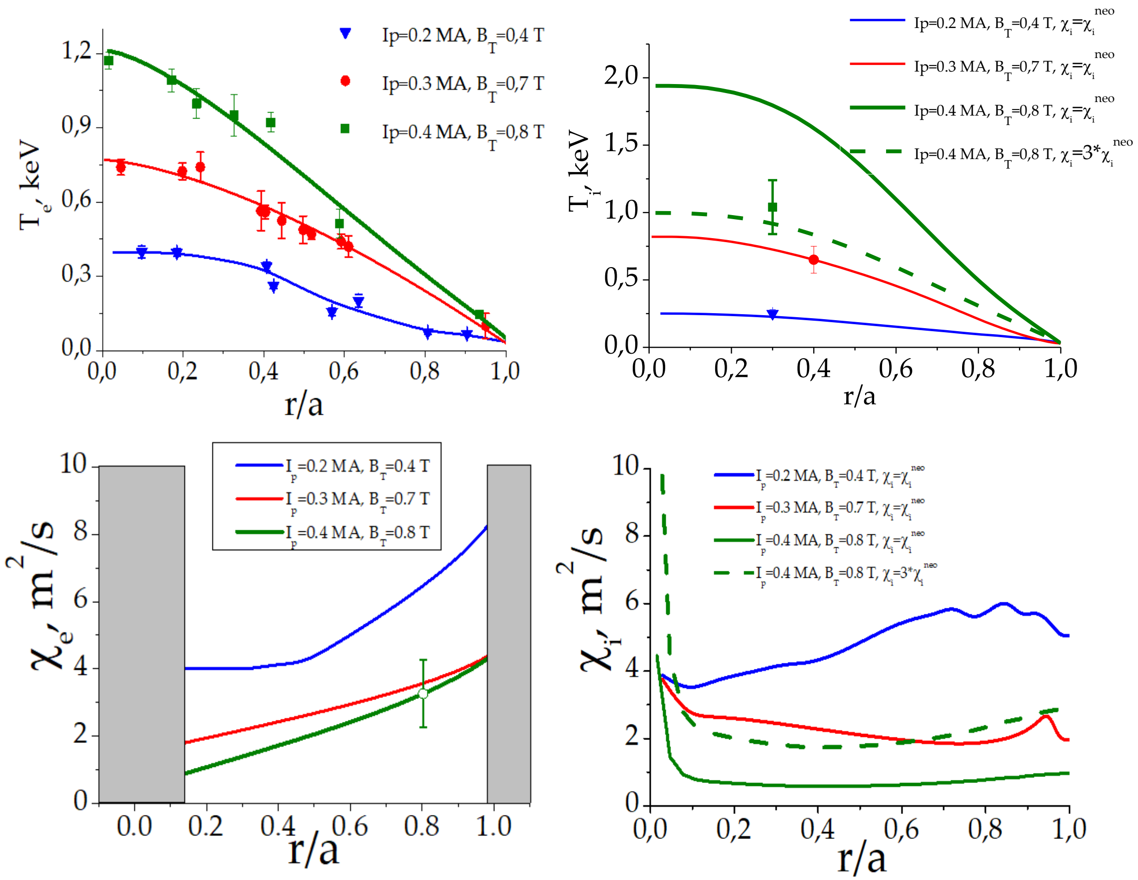






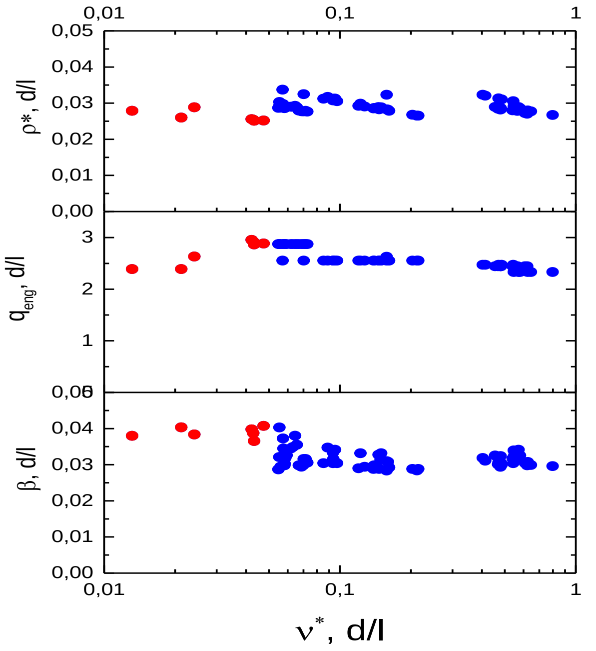
- High plasma current results in an easy access of regimes with high average density n_e = (8-10) 10^{19} m^{-3} and longer pulse duration
- Double increase of the plasma current and toroidal magnetic field results in 4-fold T_e increase in the plasma core
- The observed strong growth of the plasma total stored energy is related to the increase in of the plasma energy confinement time
- The energy confinement time values obtained for B_T=0,8 T fits well the predictions made using ST-like scaling developed at the Globus-M tokamak for B_T<0.5 T: $\boldsymbol{\tau_E \propto I_p^{0.48} B_T^{1.28}}$ *[Kurskiev NF 2019]*

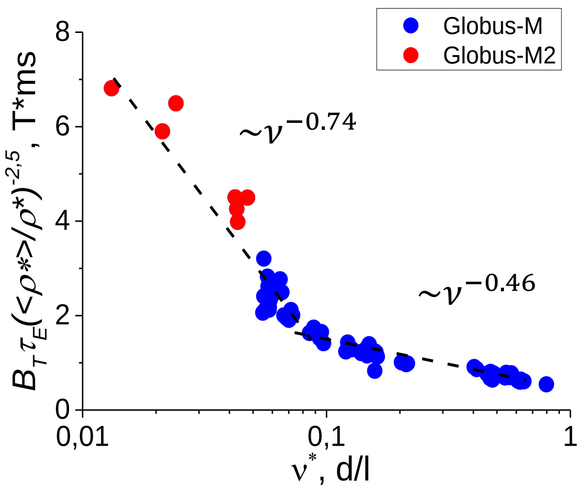
Electron and ion heat transport analysis



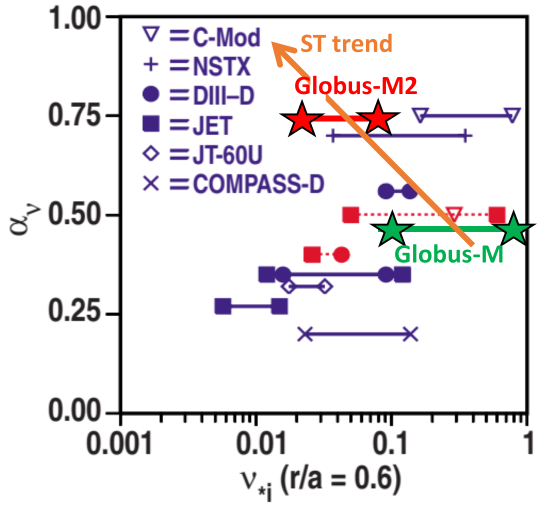
- Power balance analysis was carried out for plasma with similar $n_e = 6.5\text{-}7\cdot10^{19}m^{-3}$ and different B_T and I_p (0.4 T/0.2 MA, 0.7 T/0.3 MA and 0.8 T/0.4 MA) using ASTRA code
- The beam heating power deposition and $W_{\perp}^{fast}$ were estimated by NUBEAM and full orbit modelling with 3D-fast ion tracking algorithm.
- $W_i+W_e+ W_{\perp}^{fast}$ corresponds well to the values measured by the diamagnetic loop W^{DIA}
- $W_{\perp}^{fast}/W^{DIA} \approx 0.1$
- Both $\chi_e \approx \chi_i$ decrease in the plasma core by 2-2,5 times
- Anomalous ion heat transport contribution can be assumed for low collisionality plasma for B_T=0,8 T case.

Collisionality impact on energy confinement





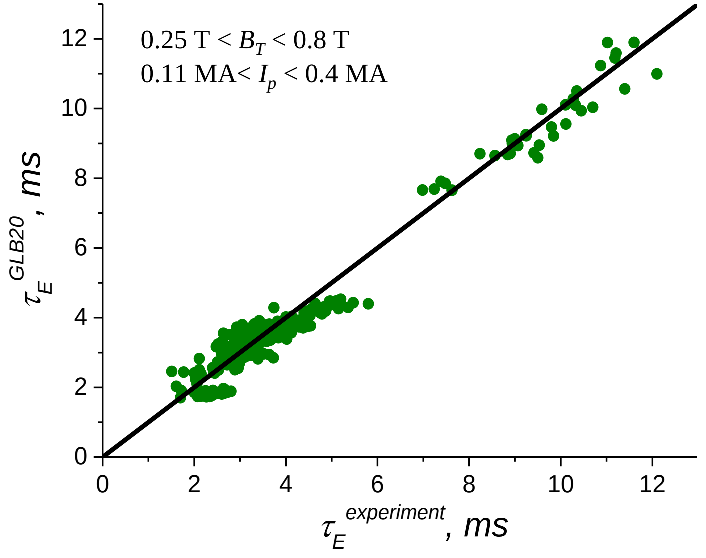
C. C. Petty Phys. Plasmas 15, 080501 (2008);



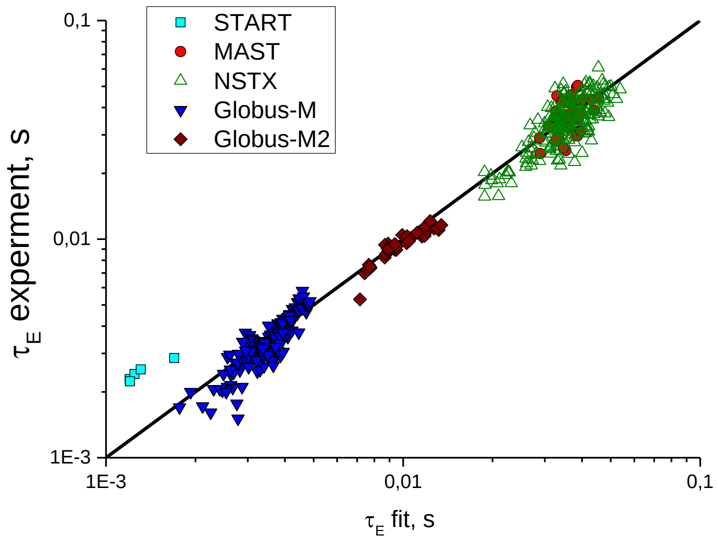
- Experiments carried out on the Globus-M2 demonstrate strengthening of the confinement dependence on collisionality for lower $\nu*$ range in ST.
- This experimental result highlights the difference between the physical processes that governs thermal energy transport in high and low aspect ratio tokamaks.

Impact of the Globus-M2 data on energy confinement scaling for ST's

$$\tau_E^{GLB\_2020} = 0.01 \cdot \boldsymbol{I_p^{0.43\pm0.22}} \cdot \boldsymbol{B_T^{1.19\pm0.1}} \cdot P_{abs}^{-0.59\pm0.23} \cdot n_e^{0.58\pm0.1}, s$$



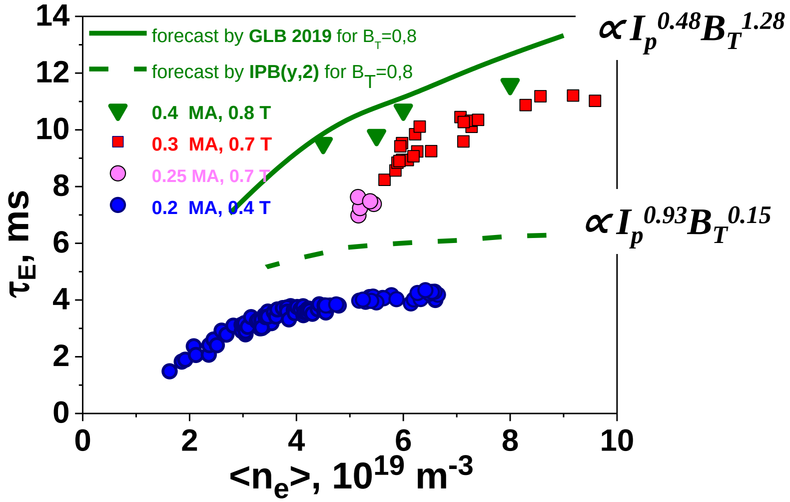
$$\tau_E^{scal} = 0.066 \cdot \boldsymbol{I_p^{0.53}} \cdot \boldsymbol{B_T^{1.05}} \cdot P_{abs}^{-0.58} \cdot n_e^{0.65} \cdot \boldsymbol{R^{2.66}} \cdot \kappa^{0.78}, s$$

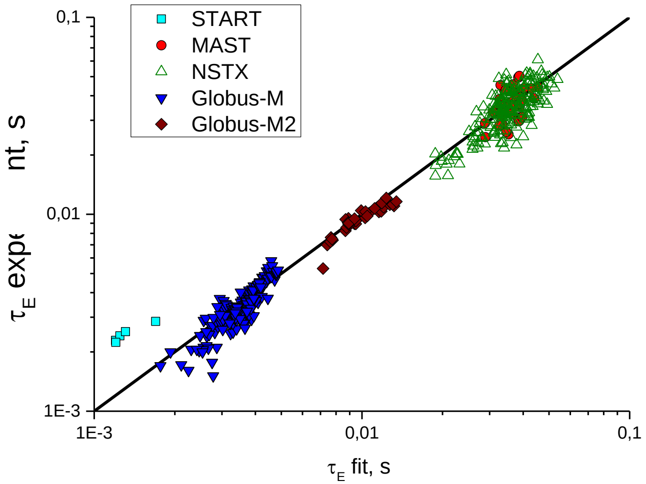


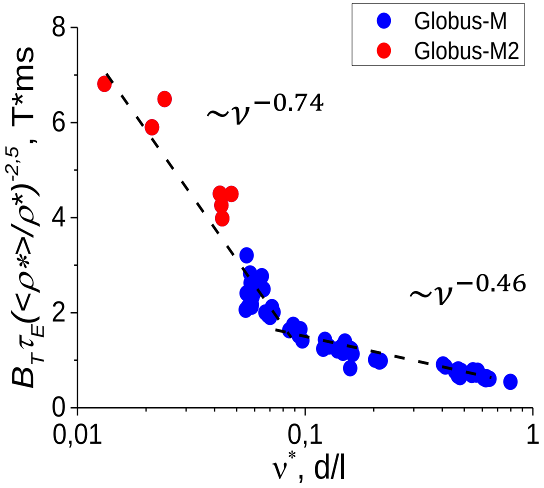
- Strong τ_E dependence on B_T and moderate on I_p is still valid for B_T = 0,8 T
- Globus-M2 data allows to estimate τ_E dependence on size for ST's

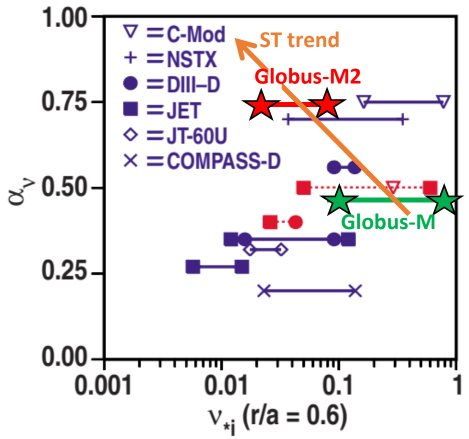
Summary slide, Globus-M2, EX-P7 659

$$\tau_E^{scal} = 0{,}066 \cdot I_p^{0.53} \cdot B_T^{1.05} \cdot P_{abs}^{-0.58} \cdot n_e^{0.65} \cdot R^{2.66} \cdot \kappa^{0.78}, s$$









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- Strong τ_E dependence on B_T and moderate on I_p is valid for spherical tokamak with B_T = 0,8 T
- A twofold B_T increase in the Globus-M2 enhances the synergistic effect of improving both electron and ion heat transport with decreasing collisionality that led to 3-fold rise of τ_E
- Experiments carried out on the Globus-M2 demonstrate strengthening of the confinement dependence on collisionality for lower ν^* range in STs, opposite to high aspect ratio tokamaks