Overview of recent work on carbon erosion, migration and long-term fuel retention in the EU-fusion programme and conclusions for ITER

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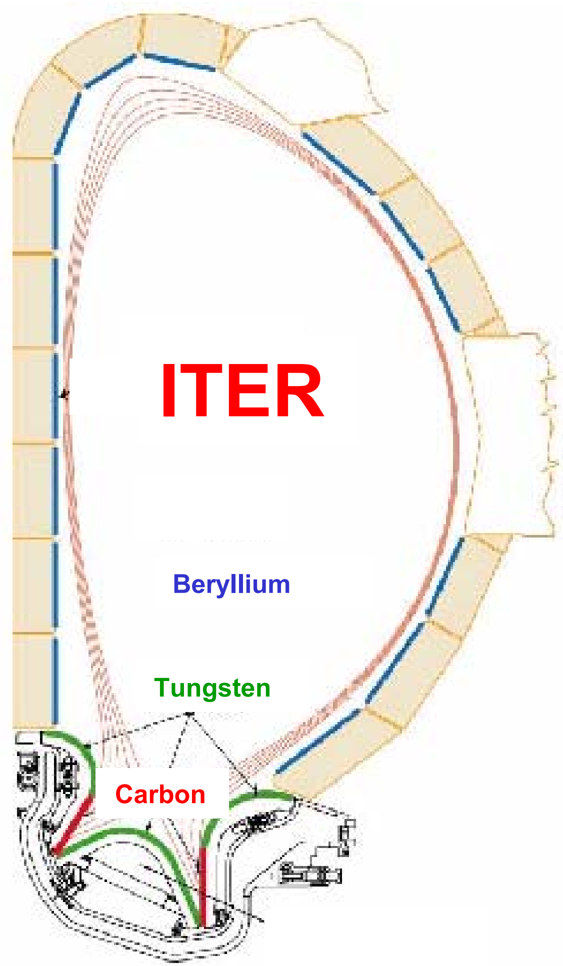
Introduction



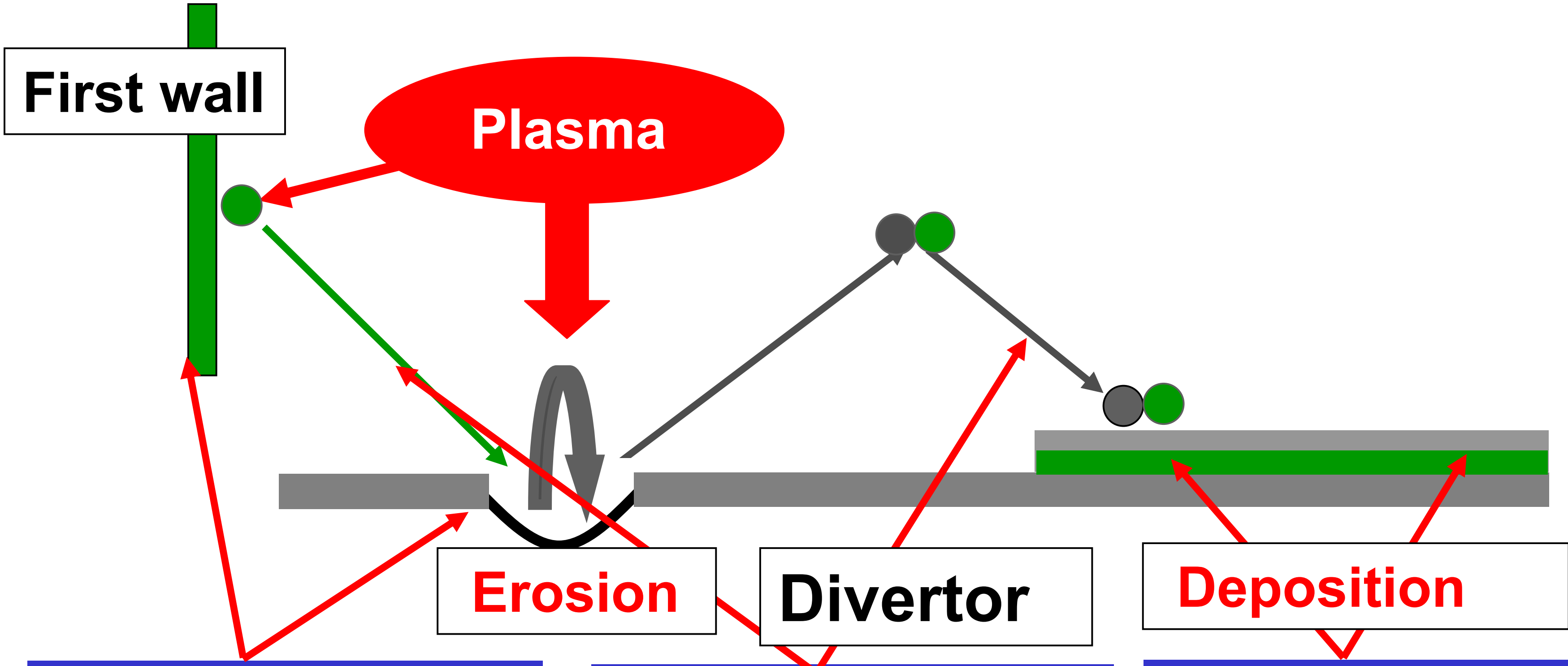
Long term Tritium inventory and lifetime of plasma facing components are most critical questions for ITER and future power plants

Understanding and development of control schemes is the major topic of the EU Task Force on Plasma Wall Interaction (related with the present ITER wall material choice)

in parallel:

The full tungsten wall programme in ASDEX-U → following talk by R.Neu

Processes that determine tritium inventory



Location and mechanism of erosion

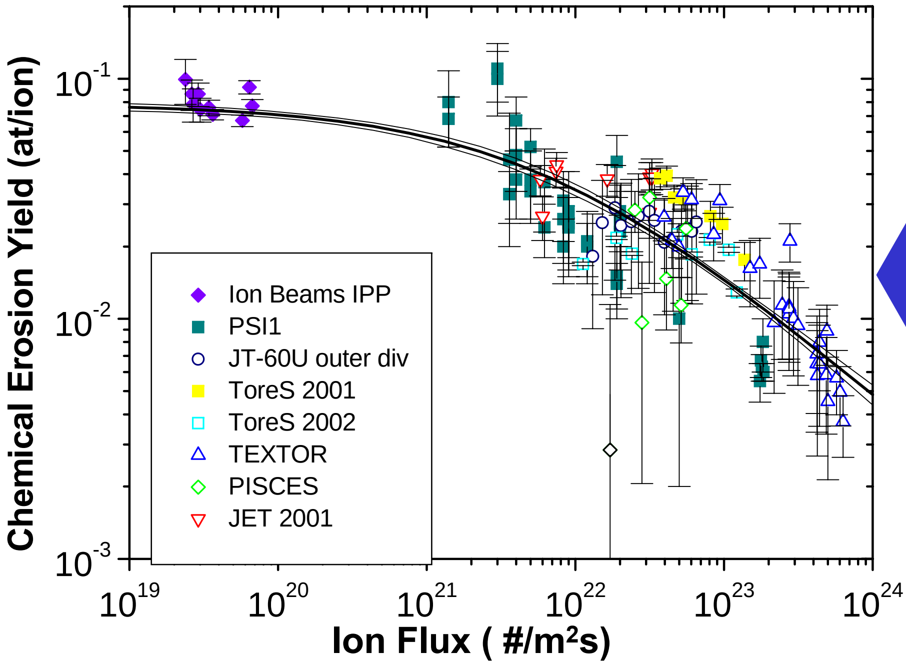
Primary erosion processes

Long and short range impurity migration

Mixed layer formation

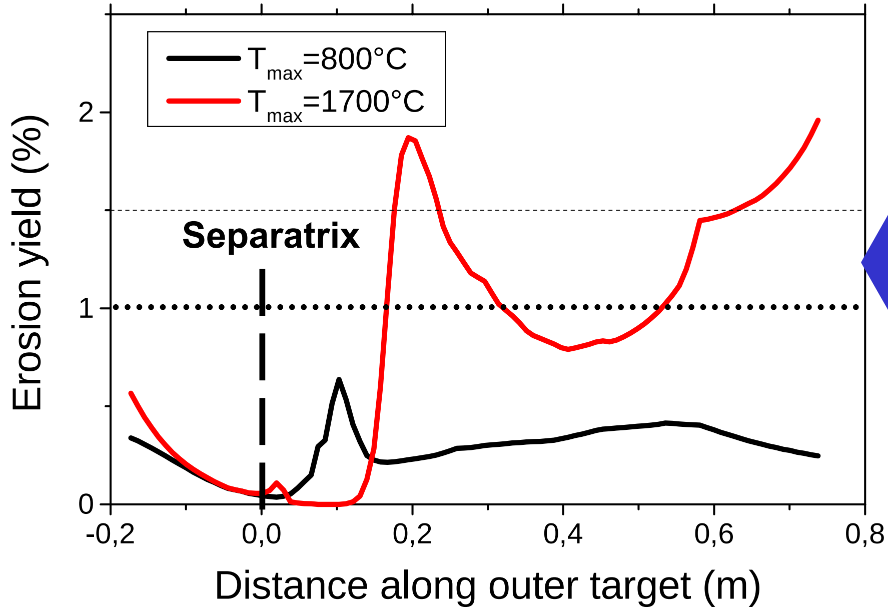
Co-deposition with the fuel

erosion: chemical erosion in divertor



Normalisation of chemical erosion data

- Ion impact energy
- Surface temperature
- Flux



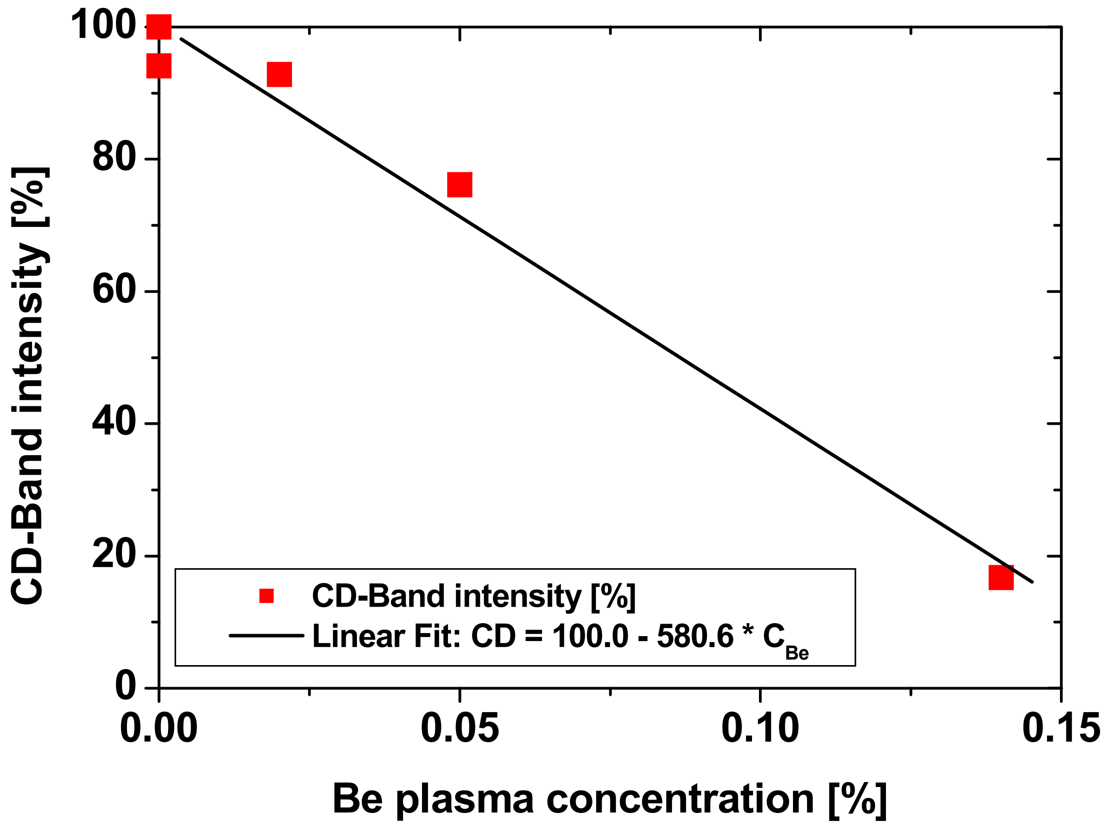
Carbon chemical erosion yields near the separatrix very low due to

- high temperature
- high fluxes
- low impact energy

Additional decrease of C-erosion by Be-deposition

Chemical erosion&Be deposition

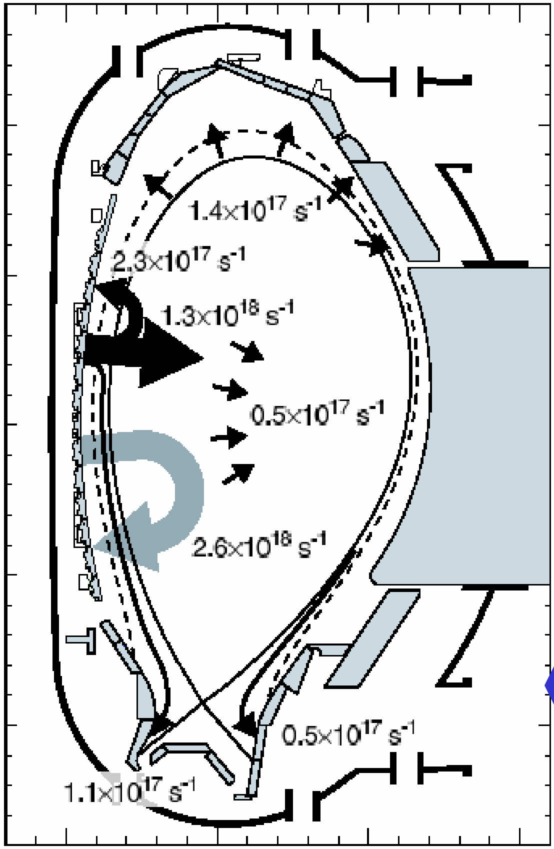
Results from Pisces linear plasma device



- CD-band decreases by ~80% for a Be plasma concentration of 0.15 %

- Be surface coverage after exposure 87% (AES).

Long range material migration

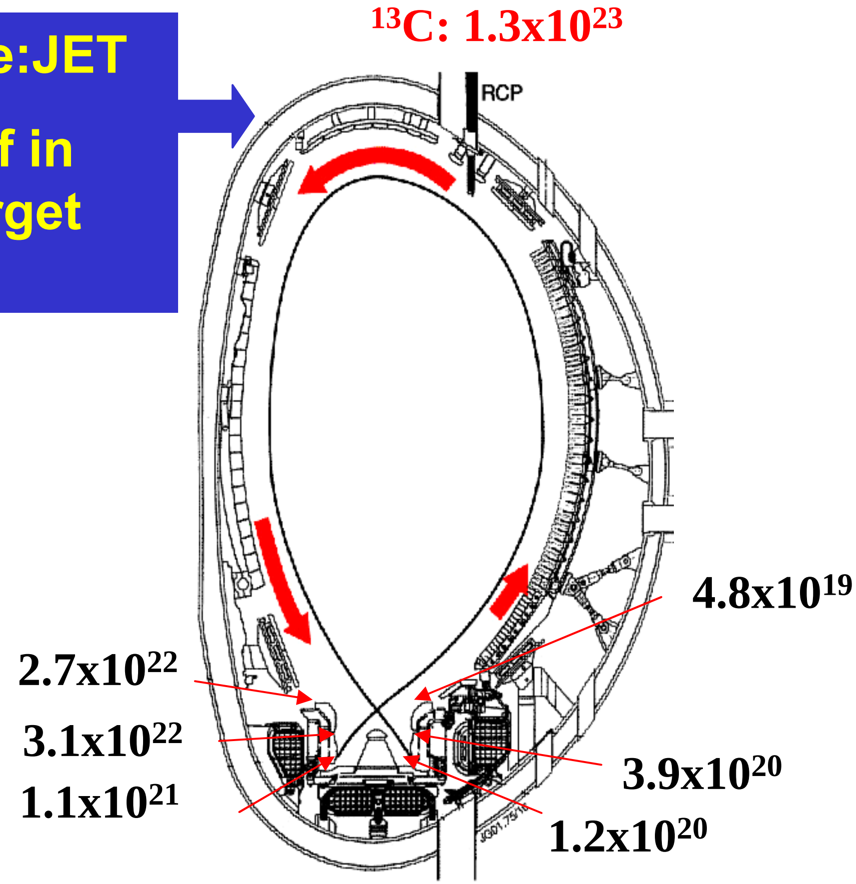


AUG

W-migration

Example:JET

$^{13}CH_4$ puff in ohmic target plasma



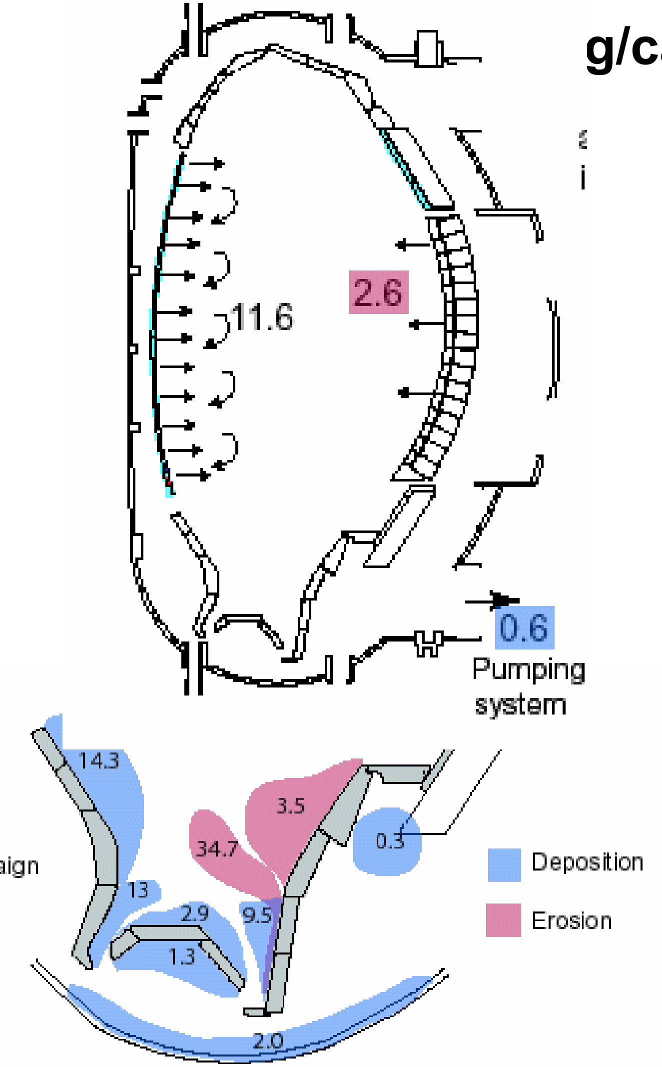
- preferential transport to the inner
- but significant deposition also in the outer divertor

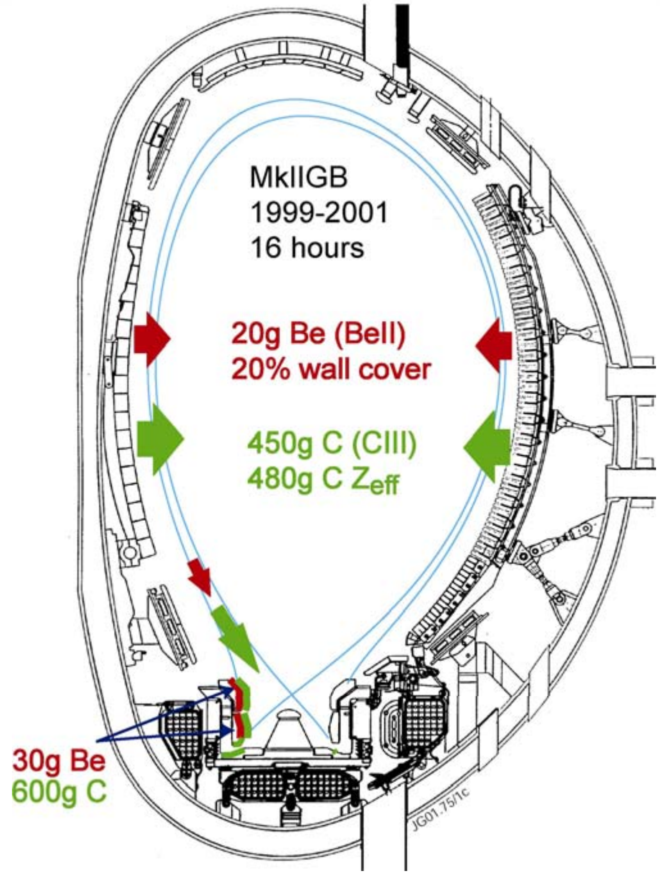
- various other results (e.g. from Be deposition) indicate that transport is exclusively to the inner divertor

No uniform behaviour of erosion/deposition of outer divertor

Global material balances: JET and AUG

g/campaign



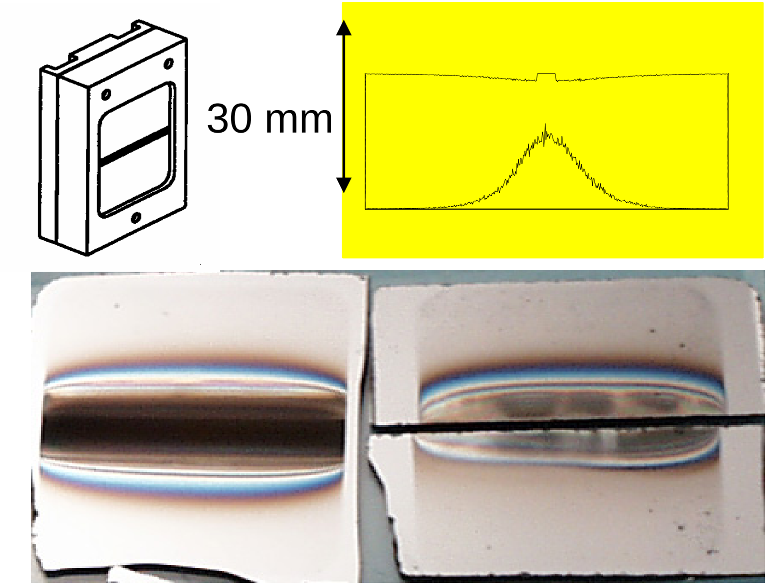


JET: balance between wall sources and inner divertor deposition, no contribution from outer divertor

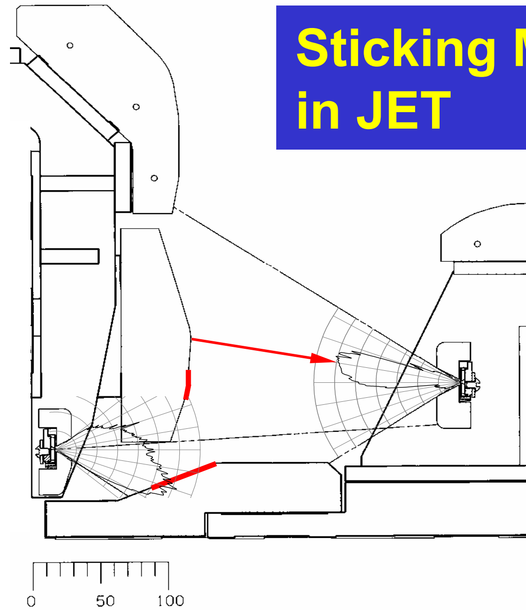
AUG: balance needs large net-source in outer divertor or strong sources in main chamber not visible by spectroscopy

Short range Material deposition

Major progress on characterisation of short range material migration



Sticking Monitors in JET



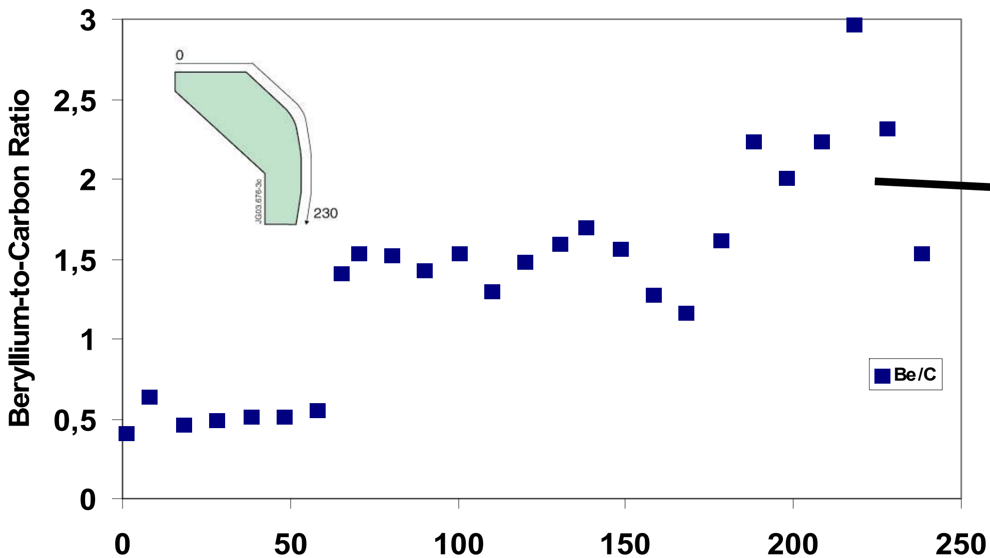
- **Majority of carbon (>99%) with high sticking (>0.9), small part (<1%) with low sticking probability (10^{-3}). The same conclusion from C deposition in TEXTOR and AUG pump ducts**

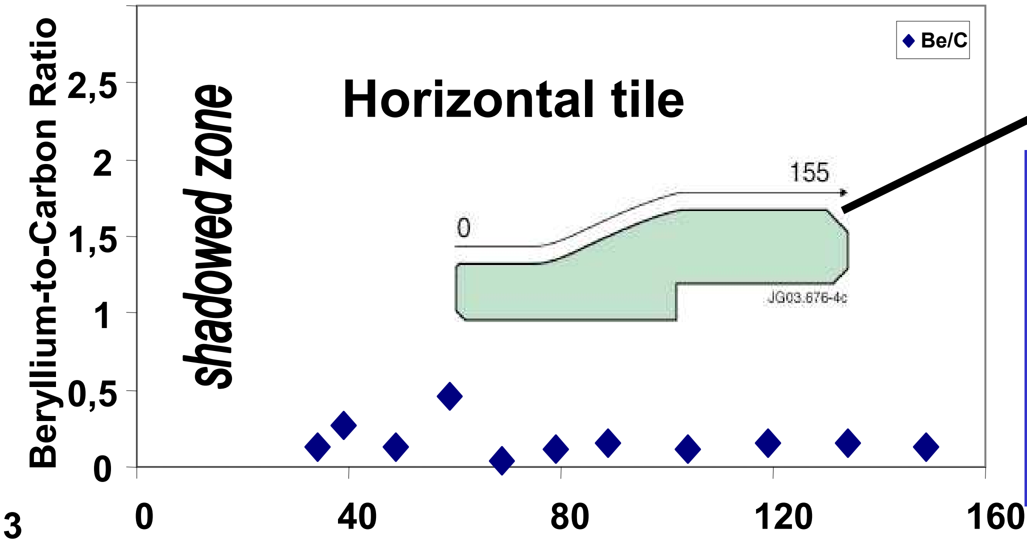
Carbon deposition is largely line of sight from the place of origin

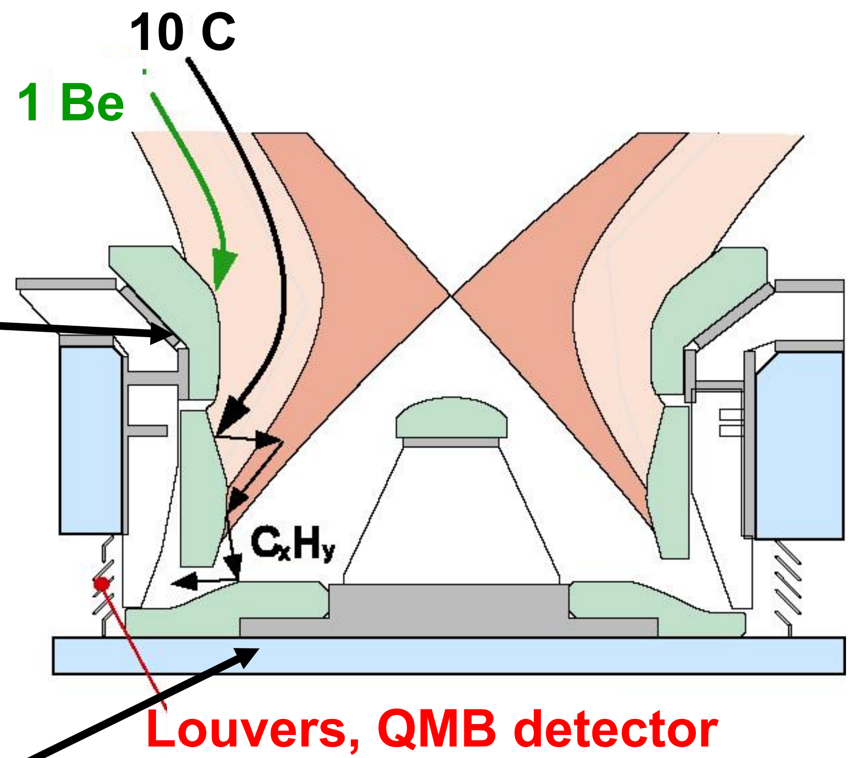
Short range material transport

Post mortem analysis

Beryllium-to-Carbon Ratio on the Divertor Tile G1C

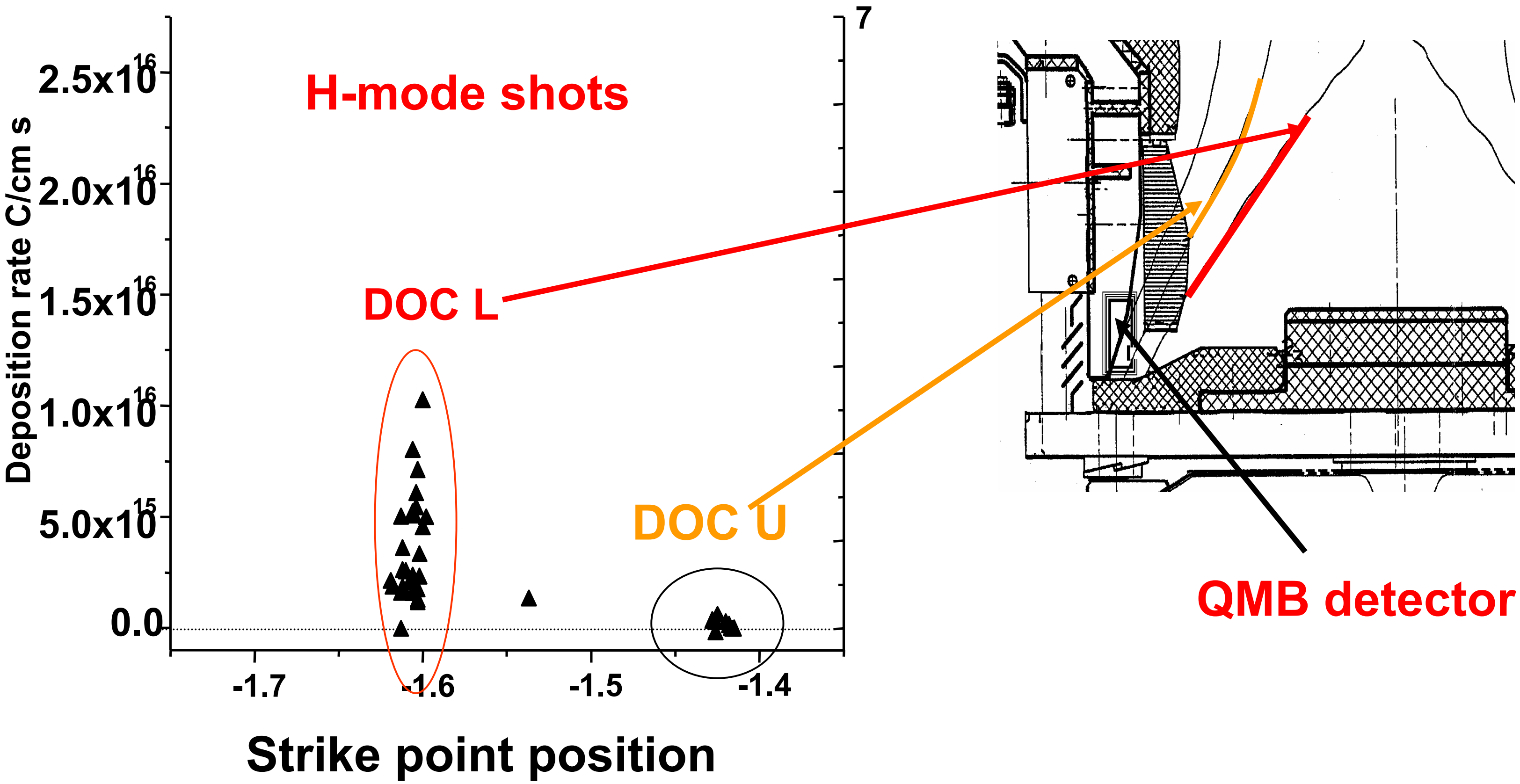






- Carbon is transported further (chemical processes)
- Be stays at primary deposition

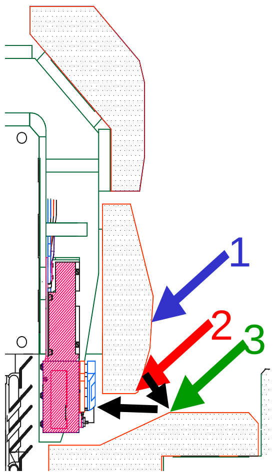
Short range material transport

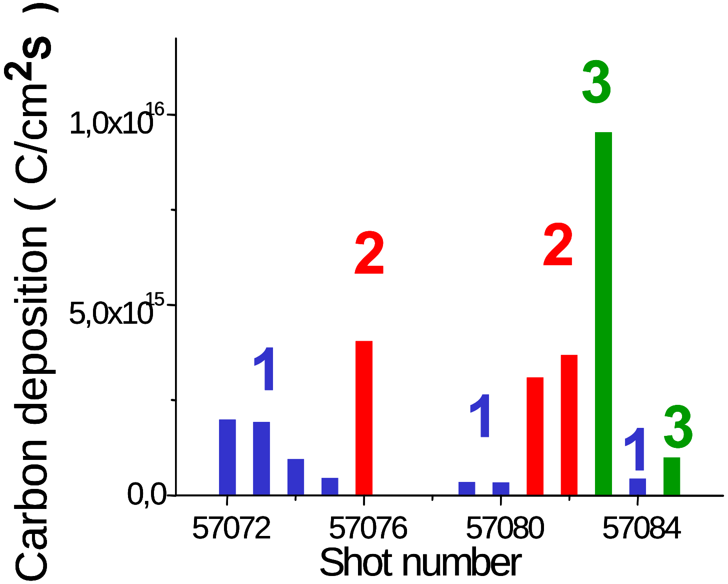


- Carbon deposition on QMB (louver) only for shots with strike point in the vicinity of louver entrance
- In agreement with ERO Code transport modelling
- Similar conclusions from AUG QMB data

Short range material transport

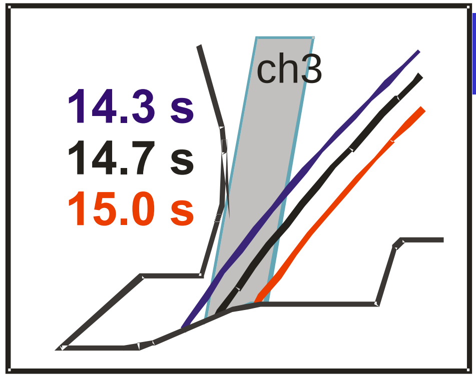
12 Reproducible L mode shots

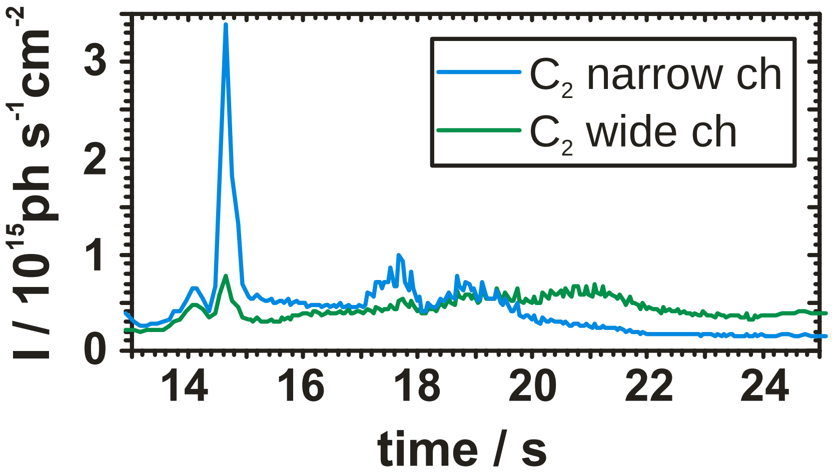




strike point

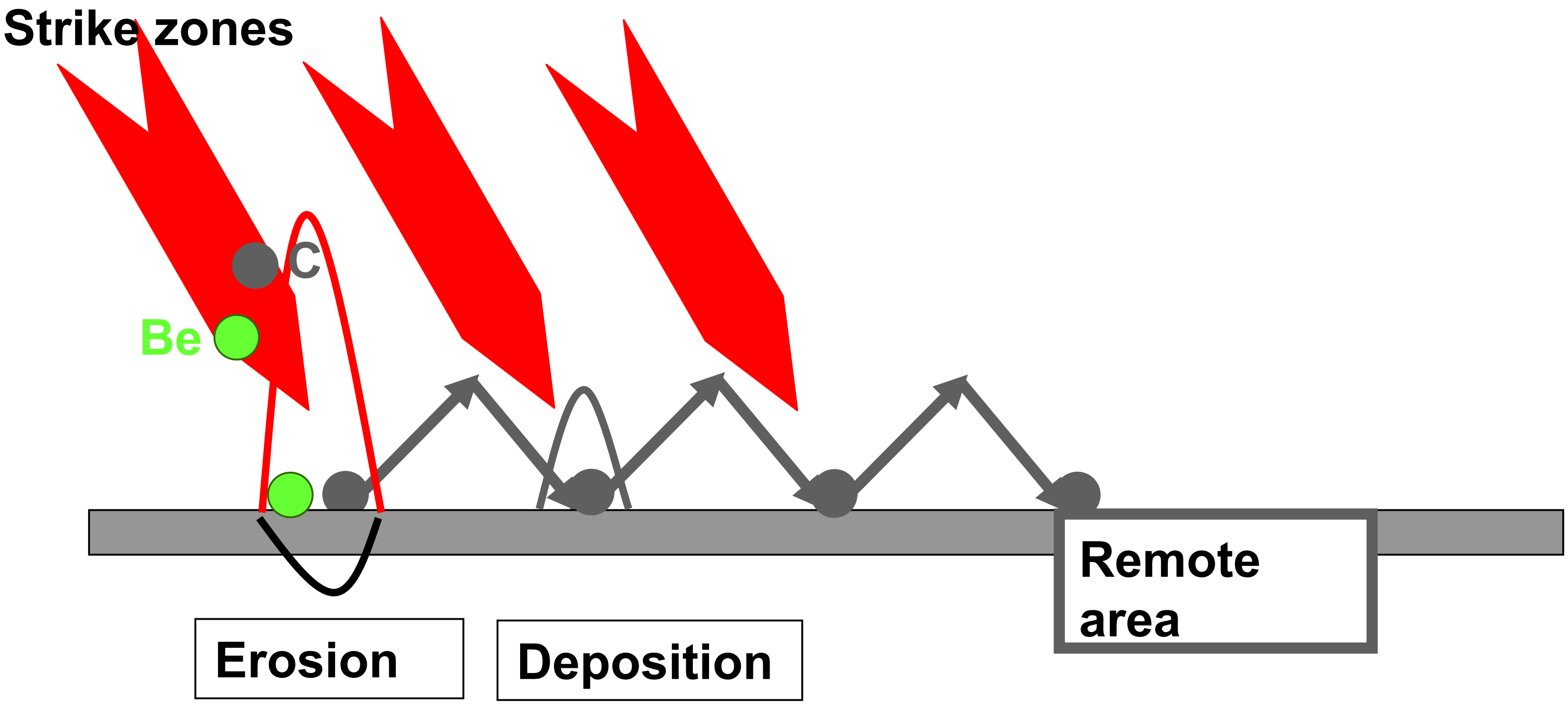
Spectroscopy





- A carbon layer is formed on the horizontal tile which is strongly eroded subsequent shots
- Carbon is transported stepwise to the louver region

Understanding of C-



Short range C- transport near strike point by chemical erosion

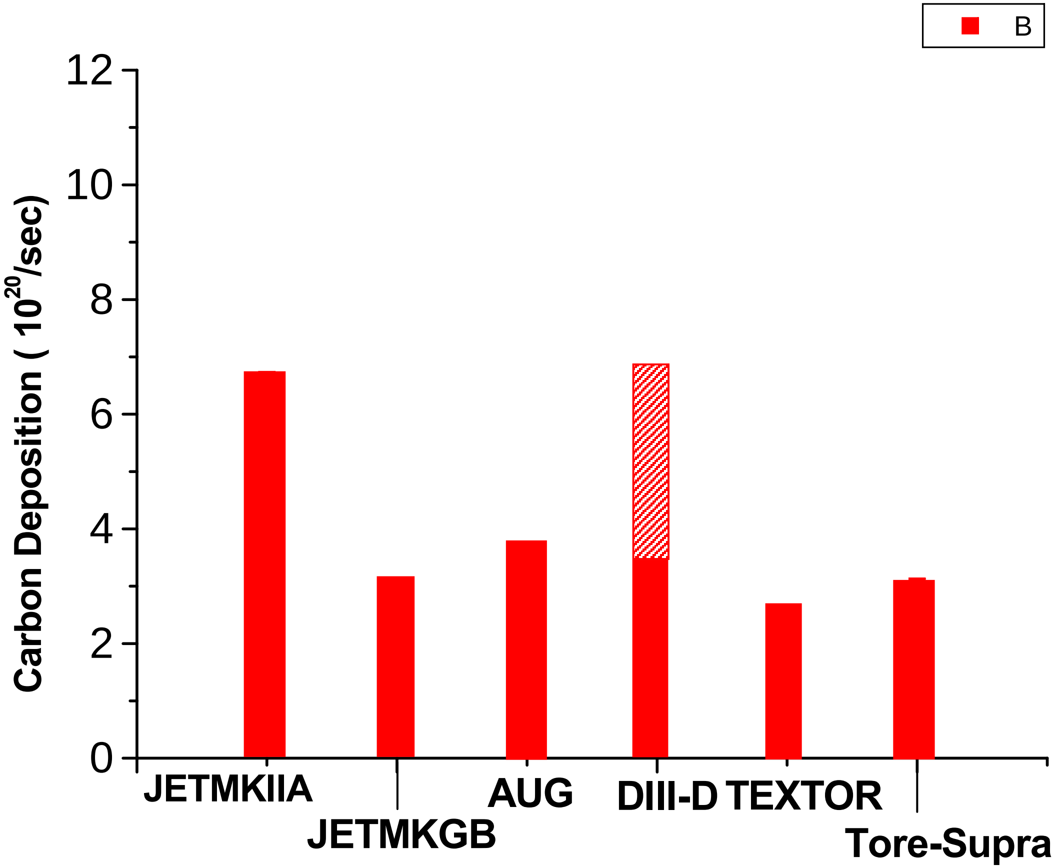
No Be transport

Transport of C to remote areas by a combination of short range transport and varying plasma configurations

no Be transport

Predictions for ITER

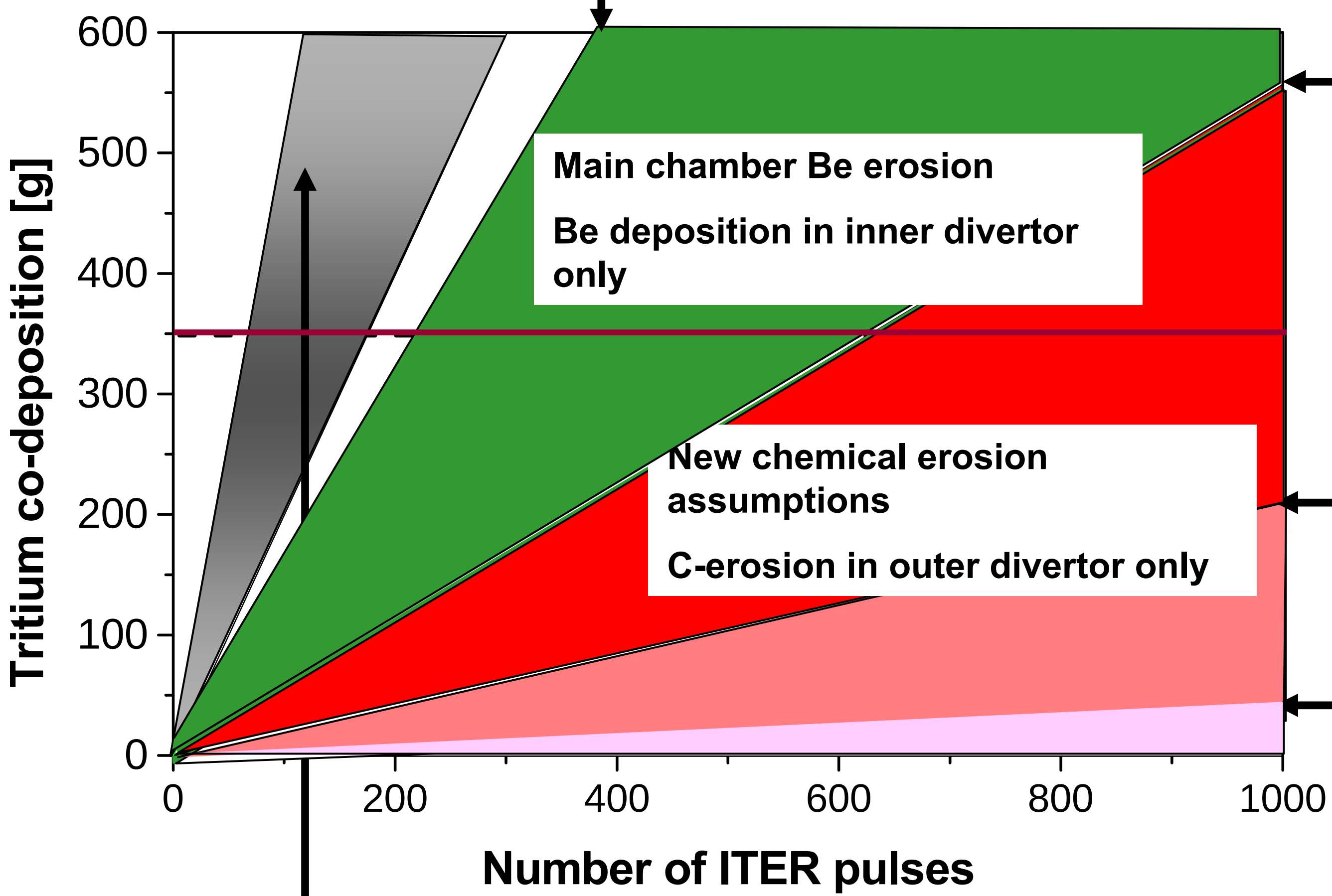
Pure empirical approach: similar campaign averaged carbon deposition rates in different machines, indicating some machine independence



Predictions for ITER

S=0, moldyn, ERO
50gBe, D/Be= 0.1

Assumption: C-erosion in outer, Be deposition in inner leg



S=0, moldyn, ERO
6gBe, D/Be= 0.001

S=0.5, moldyn, ERO
6gBe, D/Be= 0.001

S=1, ERO
6gBe, D/Be= 0.001

Previous predictions 1% chemical erosion inner&outer, Brooks& Kirschner PSI 2002

A scatter of about 10^4 between worst and best assumptions !!

Conclusion + open issues

- Carbon chemical erosion sources in ITER are smaller than previously assumed, effect of Be deposition on erosion must be clarified further
- Main chamber is a net material source in general, but more analysis about mechanism and location in present machines is strongly needed
- Outer divertor behaviour is not uniform. Edge flows are not fully understood and predictions of erosion/deposition in the outer ITER divertor are difficult
- Due to chemical C-erosion, local C and Be migration in divertor differ largely, Be will be confined largely on plasma facing sides
- Tritium retention in ITER will be reduced (compared with extrapolation from carbon devices), depends largely on the T-inventory in Be-layers and is difficult to predict more precisely