XP824 Li Pumping and Retention on NSTX

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Introduction

- Density control via Li pumping of D is goal of multi-year Li program on NSTX but Li pumping has not yet been measured directly.
- XP aims to measure the fraction of the injected deuterium that is retained in the NSTX vessel both before and after PFCs are coated with fresh (active) lithium.
- The static vessel pressure rise will be measured after ohmic and RF discharges with all the valves closed and compared to a gas-only shot.
- Part 1 of XP824 aims to measure carbon pumping before Li evaporation.

Joint US tokamak FY 2009 milestone on pumping and retention:

- Conduct experiments on major fusion facilities to develop understanding of particle control and hydrogenic fuel retention in tokamaks. In FY09, FES will identify the fundamental processes governing particle balance by systematically investigating a combination of divertor geometries, particle exhaust capabilities, and wall materials. Alcator C-mod operates with high-Z metal walls, NSTX is pursuing the use of lithium surfaces in the divertor, and DIII-D continues operating with all graphite walls. Edge diagnostics measuring the heat and particle flux to walls and divertor surfaces, coupled with plasma profile data and material surface analysis, will provide input for validating simulation codes. The results achieved will be used to improve extrapolations to planned ITER operation. (* text updated, shown as accepted by DoE)

Overall Strategy

- Retention differences between Li / no-Li could be small so target is to measure retention with ~1% accuracy. This is beyond the previous scope of the pressure gauges and RGA.
- Basic equation:

$$\text{Retention} = 1 - \frac{\text{Ion gauge 'IG\_110' rise with discharge}}{\text{Ion gauge 'IG\_110' rise with gas-only shot} * Q}$$

$$Q = \frac{\text{Drop in Inj \#2 sensotec pressure (PE\_102) with discharge}}{\text{Drop in Inj \#2 sensotec pressure (PE\_102) with gas-only shot}}$$

Part 1 of XP deals with no-Li baseline dynamic retention in carbon/stainless….
XP also aims to identify path for a more accurate measurement and calibrations and simulations in 2009.

(Sensotecs monitor pressure in gas injection plenum.
Ion gauges: 'IG_110' is next to RGA at end of pump duct, 'IG' is next to vessel.)

Proposed shot list - 0.5 day:

Assume previous XP ends with usual 10 min He-GDC.

Gas-only calibration (2-3 shots):

- 2 gas-only shots, check relative retention < 1%.
- If > 1% then vessel is still outgassing, one more gas only shot - then continue.

Discharge development (3-5 shots)

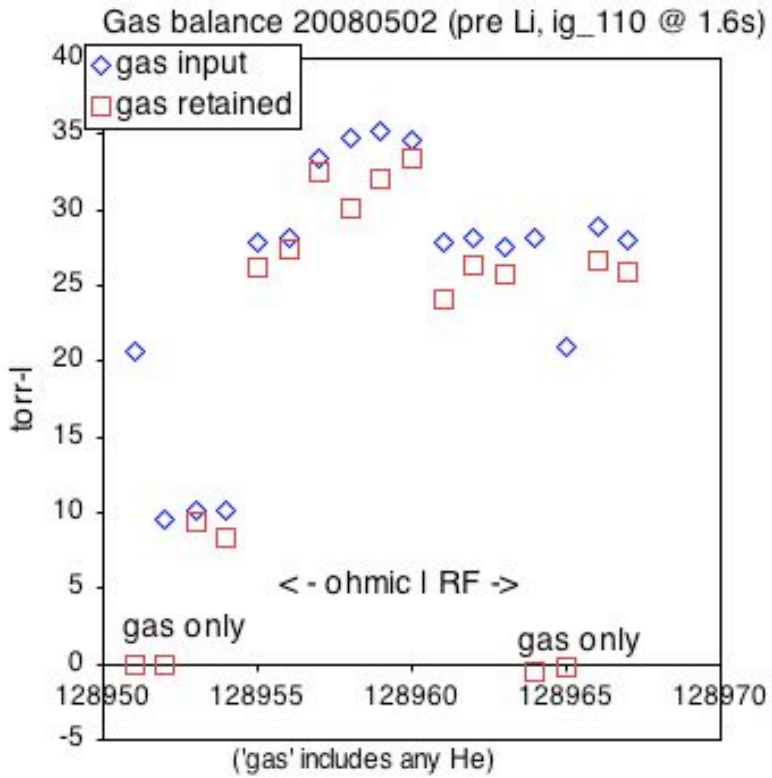
- use the RF conditioning shot #128133 for reference
- Drop Bt to 0.45 T
- Ramp down the current before OH runs out, e.g. at 0.5 sec. to make sure it is smooth
- NB valve is always closed. TMP valves close 30 s before shot. (RGA valve is open)
- TMP valves remain closed for 2 mins followed by HeGDC.
- Establish He-GDC needed for consistent discharges (5 mins ?)
- Repeat optimal Ohmic Discharge
- Repeat gas-only calib. (total 7-10 shots so far)

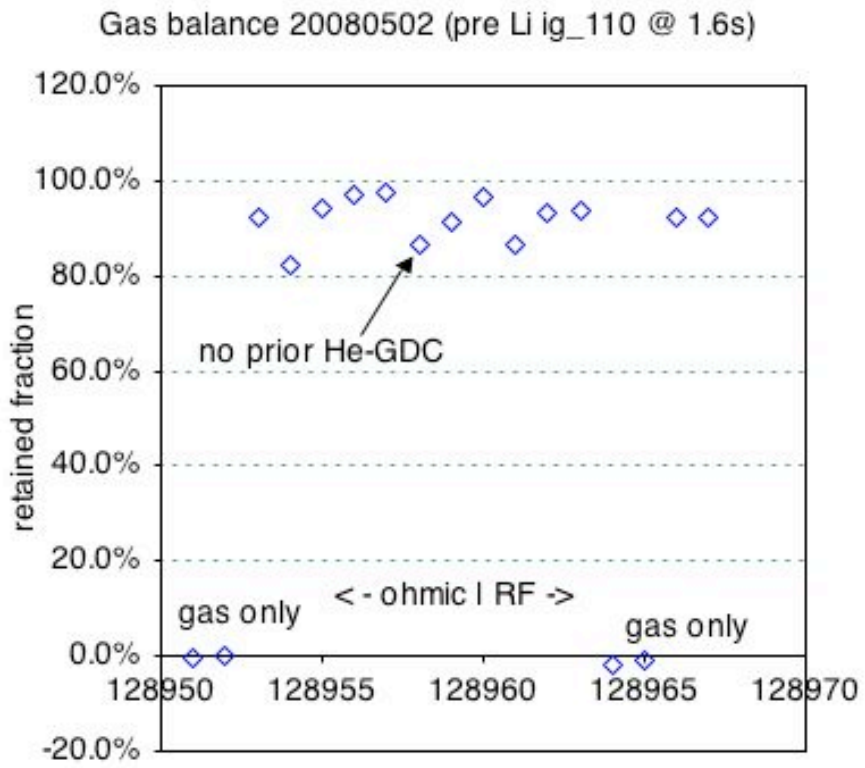
RF discharges (5 shots)

- Three @ 0.65 MA, 1.5 MW RF power, (enough to get into H-mode?). Could use ohmic discharges as baseline, with steady RF power added during flattop and maybe part of rampup.
- Repeat gas-only calibration.
- Final RF discharge as above, no HeGDC following, leave all valves closed over weekend to track long term outgassing.
- If time runs out skip RF part, but finish with additional ohmic leaving valves closed.
- *Repeat when LiTER operates and 10,20,30 mins after LiTER shutter closed.*

Results: Retention 85 - 97% @ 1.6 s

- Compare gas input to vessel pressure rise (IG110 averaged over t= 1.2 - 2 s)
- Gas retained calculated from comparison to gas-only shot.



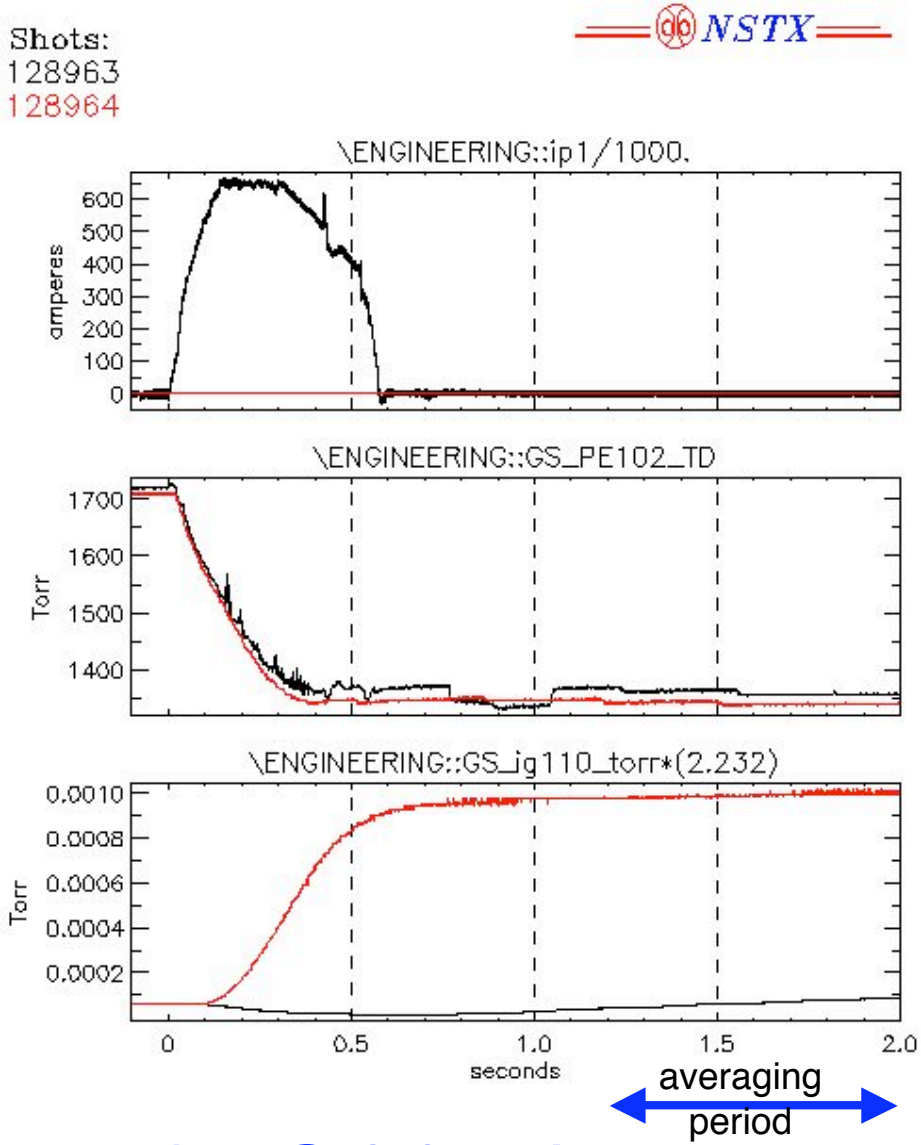


- Slightly -ve (-2%) retention on gas only 128964 from outgassing
- RF increases integral stored energy 11kJ-s > 16 kJ-s - no major change in retention.
- Not much headroom to measure effect with Li

Plasma / gas-only comparison

Overview:

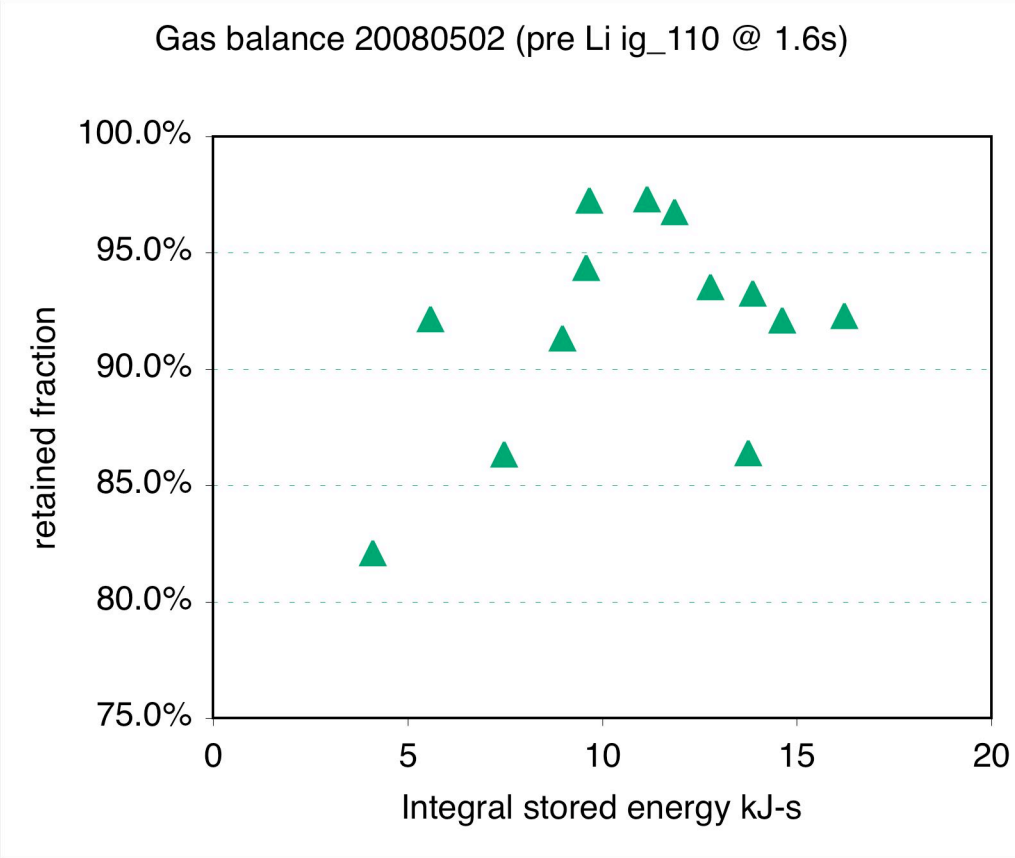
- NB TIV closed
- TMP TIVs closed @ -30s
- 2 gas-only shots confirmed negligible retention (-0.5%)
- 650 kA, 4.5 kG, adjusted density (after 3x GDC) and optimized IP rampdown (5 shots)
- Retention 82% - 97%
- Omit HeGDC prior to 1 shot
- Retention dropped 97% to 86%
- Then add ≤ 2.6 MW RF
- Integral stored energy increased from 11 ohmic to 16 kJ-s with RF.
- Increase TF from4.5 kG to 5.5 kG to avoid locked mode
- Retention 91% - 97%



99% retention @ 0.65 s !

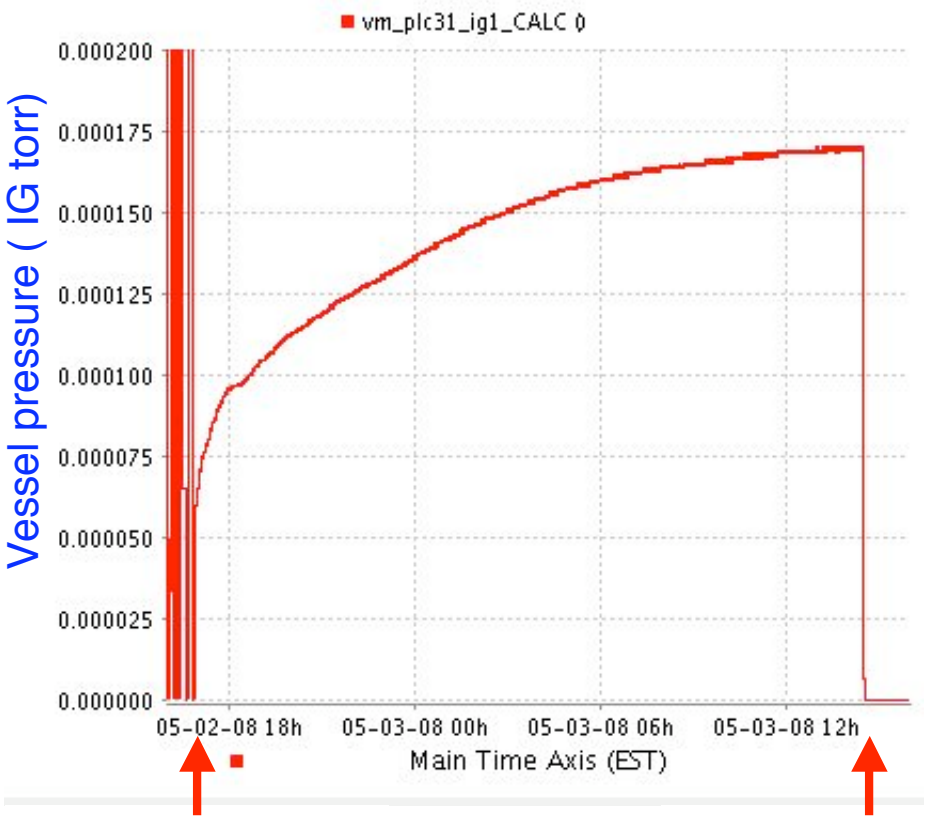
Retention vs. $\int$ stored energy (kJ-s)

- No clear correlation with stored energy



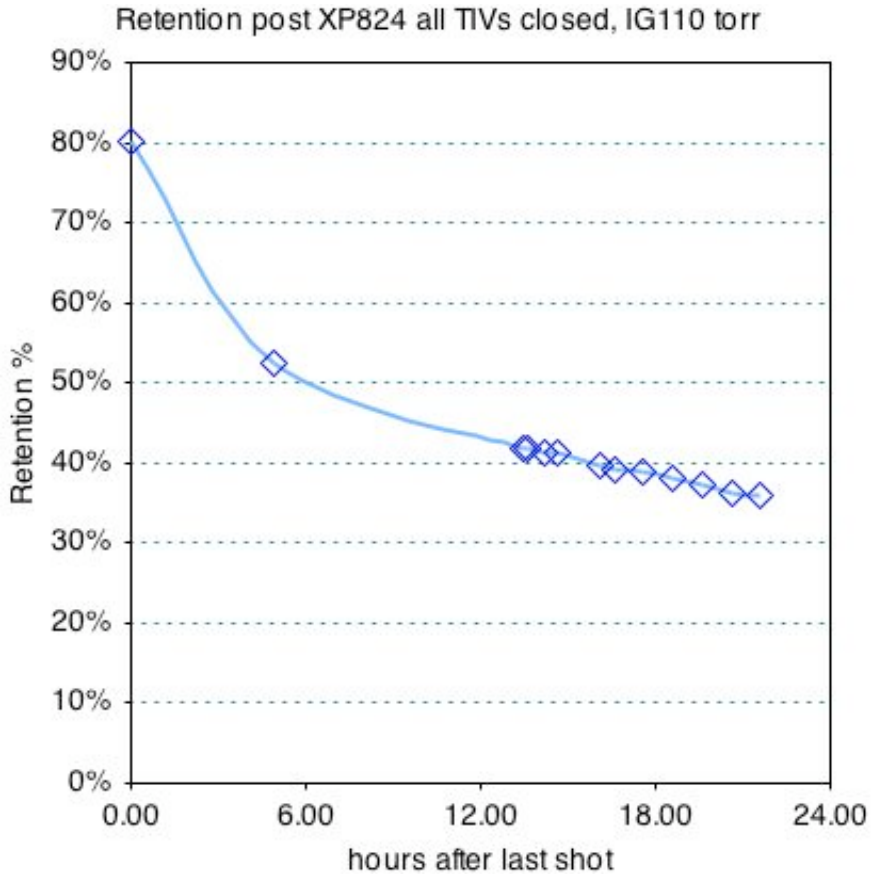
Longer term retention

- Leave all TIV's closed for 21.5 h Friday PM - Saturday end of 1st shift.
- Monitor outgassing pressure rise on IG and IG110.



End of XP824 TIVs closed before final shot Friday

TIVs opened Saturday 2:30 PM

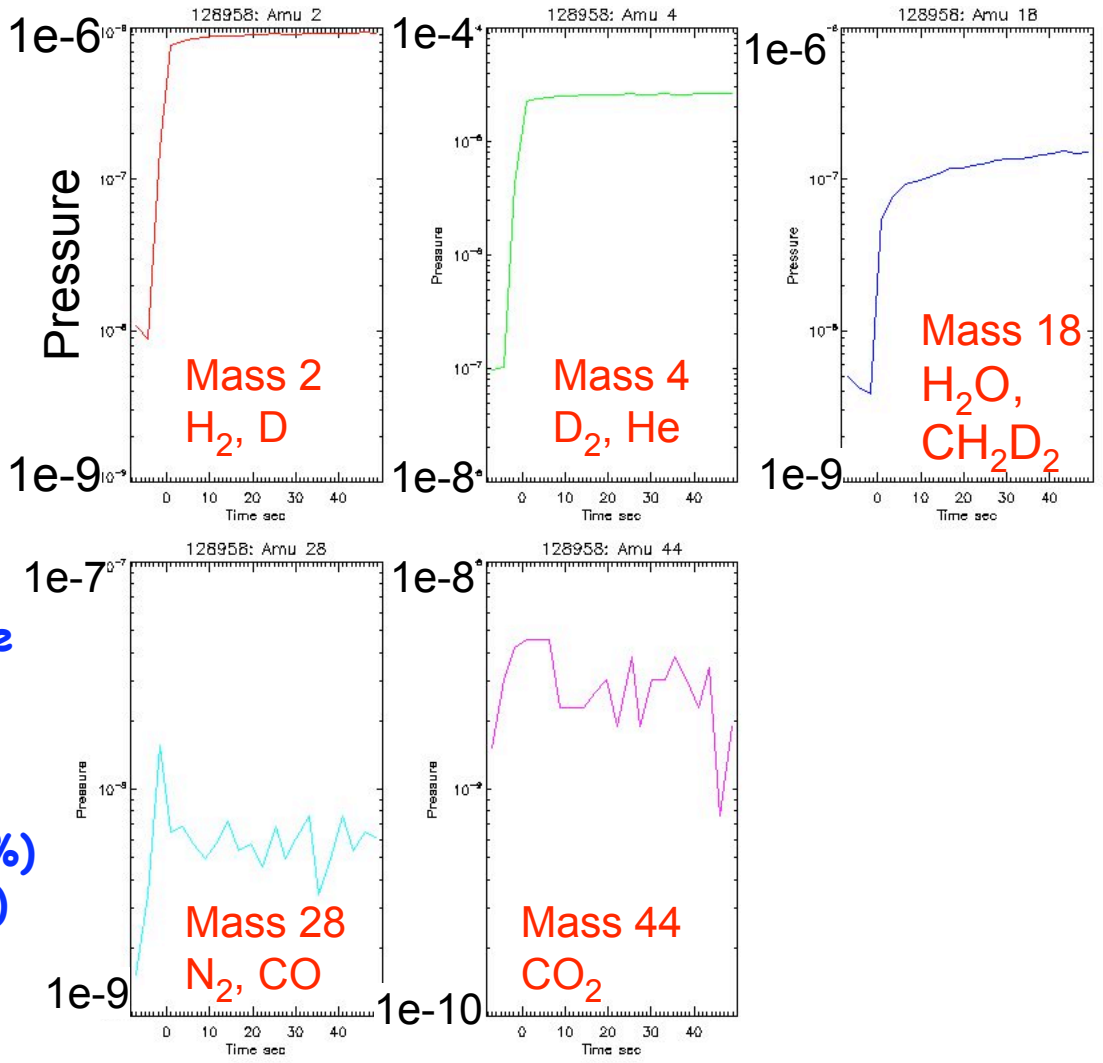


Impurities ?

- Mass 4 = 2.5e-5 'pressure'
- Mass 18 = 1.5e-7 'pressure'
- RGA rise on mass 18 ~1% of mass 4
- No data on He / D ratio (commercial Penning gauge needed)

CONCLUSIONS:

1. **Nearly all D immediately retained in carbon tiles.**
2. **Outgasses over > 1day.**
3. **Not much headroom for Li to make an easily measurable difference.**
4. **Modelling needed to understand results in context of fueling efficiency (expected to be 10-30%) and recycling (expected to be ???)**



Thanks to:

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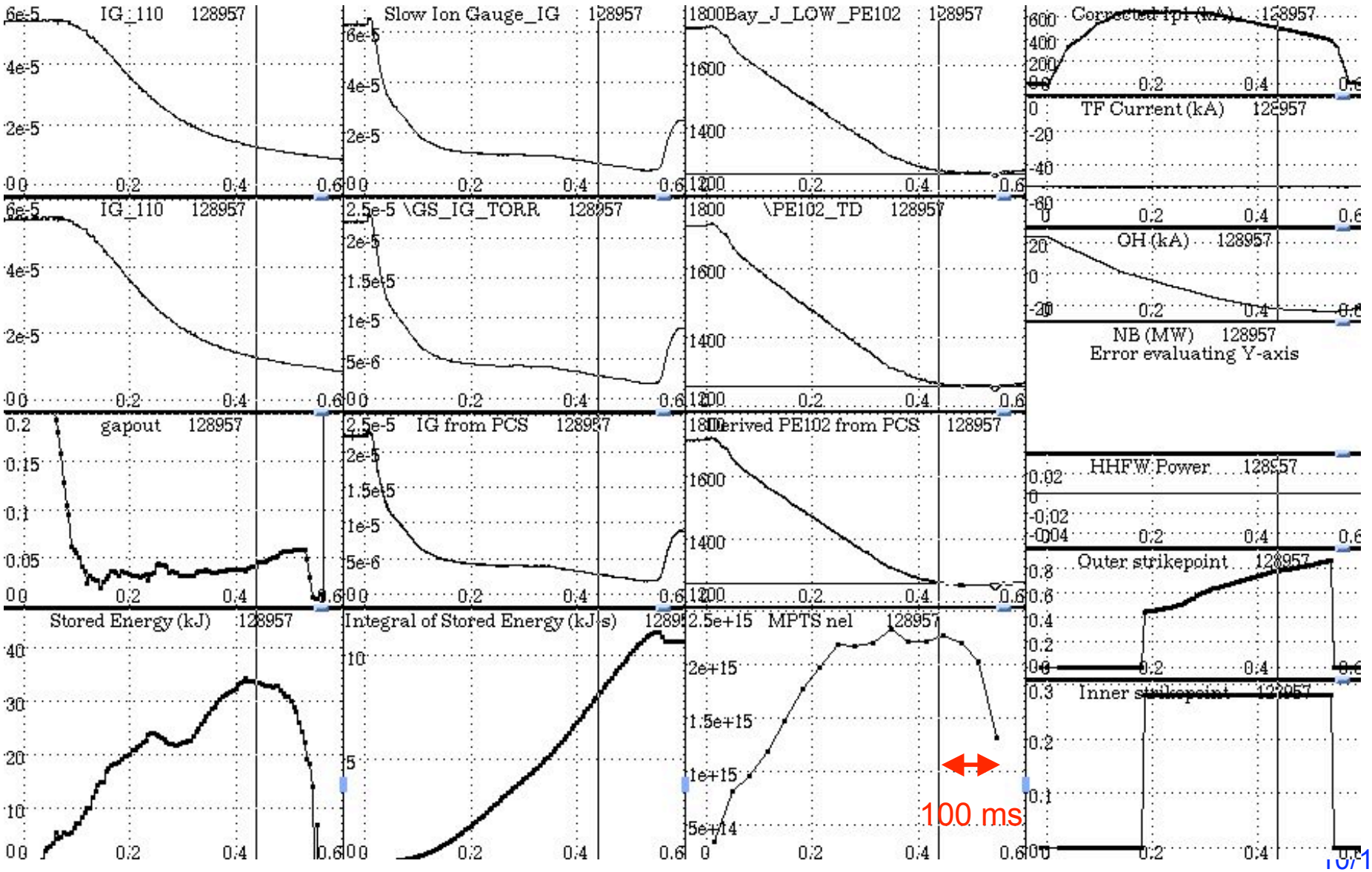
Extras…

Relation to recycling coefficient ?

- Density pumpout in ~ 100 ms after end of gas injection (just before Ip rollover)



Uncertainties: ion gauges, sensotec :

"Retention" Summary:	All gas-only shots	IG	IG_110	IG	IG_110
4/3/08		scope point	scope point	IDL	IDL
2-puff	128266 use as calib shot	0%	0%	0%	0%
2-puff	128267	2.78%	1.65%	0.59%	0.147%
4-puff	128268	1.97%	-0.33%	1.41%	-0.838%
4-puff	128269	2.30%	-0.45%	1.70%	-0.785%

- Deviations from zero due to bit noise etc -improved with IDL averaging.
- Uncertainties in absolute gauge calibrations and vessel and plenum volumes cancel out (but NIST calibrated baratron would be helpful).
- Commercial Penning gauge needed to distinguish He and D2.
- Modelling needed to understand results in context of fueling efficiency (expected to be ≈ 20%) and recycling (expected to be ???)

Uncertainties- Gas composition

- Planned 2-shot comparison does not rely on absolute measurements of pressure or plenums - just sensotec/ion gauge linearity and tracking impurities.
- Gas calibration shots show 'IG_110' ion gauge linear to < ~ 1%
- Minimise secular changes by performing gas-only shots on run day.

'IG' measures total pressure - what about impurity gasses water, CO etc…?

- If impurities < 1% it would simplify analysis.
- If impurities > 1% need both RGA 'gauge factor' and ion gauge 'gauge factor'
- Gas-only 129269 mass 18 etc / mass 4 ratio ~ 0.3% (impurities negligible)
- Plasma exhaust: 128288 4/4/08 2MW NBI impurities < 1% on shot RGA !

Tracking Helium (from HeGDC) ?

- RGA more difficult, mass 4 = both He/D_2 , need cracking pattern of He and D_2.
- Penning Gauges better - but commercial unit needed to excite low pressure He.

- For absolute pressure calibrations a new 1 mtorr Baratron with fresh NIST calibration is required.