

Are we taking it seriously? How can we make it safer.

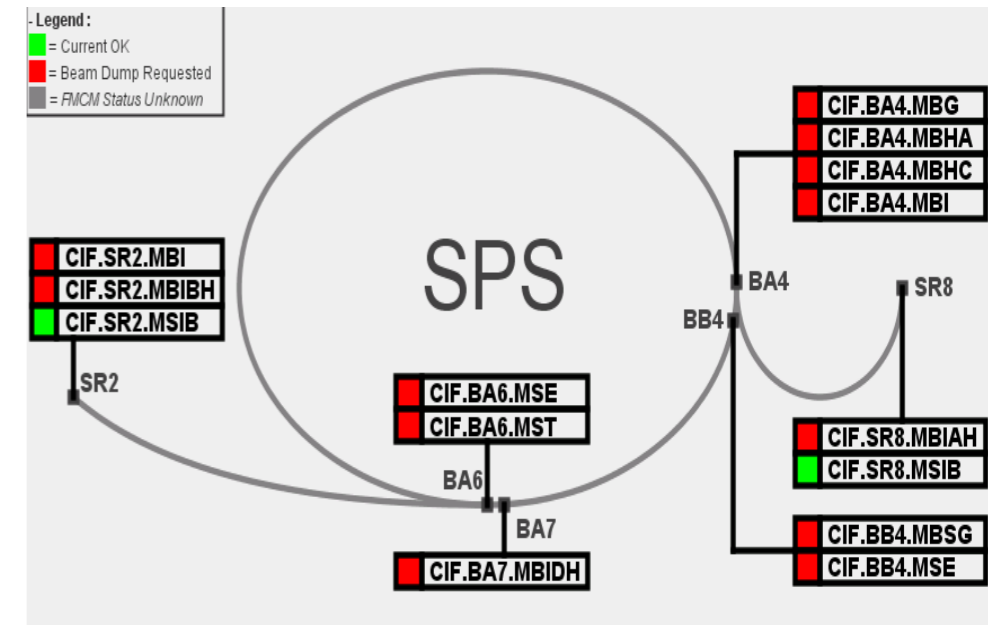
INJECTION PROTECTION

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Injection Protection System has to protect against a number of failures

all of which are SINGLE TURN FAILURES

- o Injection into LHC at wrong settings
- o SPS extraction + Transfer line failures: wrong trajectory through line or into LHC
- o MKI failures: does not kick, kicks at the wrong moment (synchronisation problem), flash-over, erratic



Protection:

- o Beam presence
- o Beam position interlock at extraction point, **power converter settings interlock** + FMCNs, **transfer line collimators (TCDI)**
 - Dipole chains: interlock at 0.1 – 0.2 %
 - Quadrupoles: interlock at 0.5 %
 - Dipole correctors: 15 urad
- o **Protection against MKI failures: TDI (+TCDD) + TCLIs**

- o = inject intermediate batch before going for high intensity filling

- o LHC 2010 nominal beams: 3 booster rings, harmonic 2
- o Intermediate intensity: single booster ring only – manual (slow) change in 2010
 - 75 ns: 8 bunches (x2, x2)
 - 50 ns: 12 bunches (x2, x3)
 - 25 ns: 24 bunches (x2, x2, x3)
- o Possible approaches 2011
 - Separate user
 - NEW LHC injection requests

- o Separate user:
 - Advantage: can take the lowest possible intensity: 8 bunches
 - Disadvantage: COPY of steering, need to change cycle in the middle of the filling – again slow

- o We prefer: NEW LHC injection requests

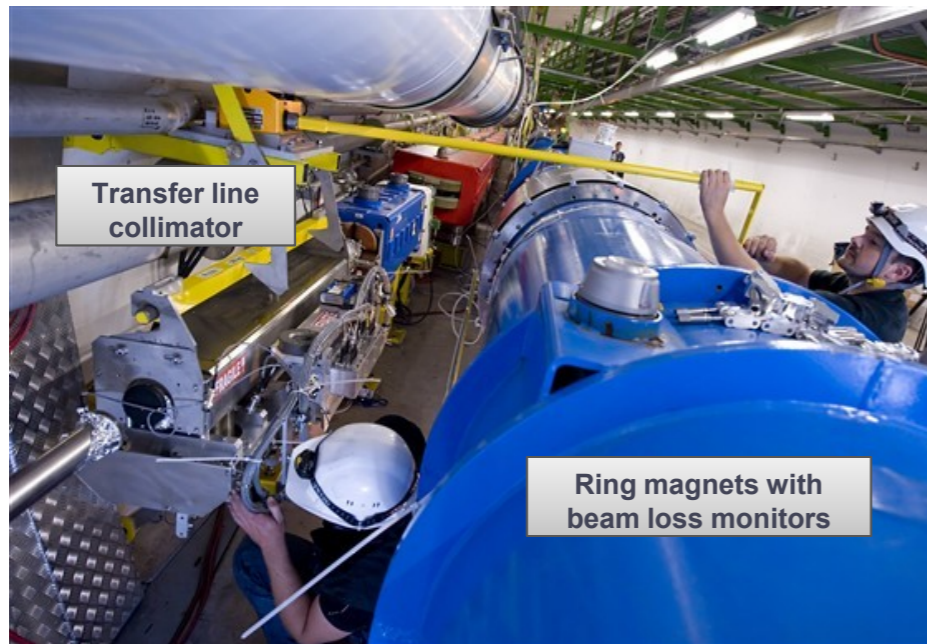
- o Concept to have different destinations for the booster rings exists already.
 - Different settings exist in PS for different booster ring destinations
- o Idea: make the destinations of the booster rings dynamic
 - LHC asks for number of booster rings: 1,2,3, 4
 - Gives also a lot more flexibility in defining LHC filling schemes.
- o Current LHC injection scheme:
 - Number of PS batches
 - New: number of PS batches and number of booster rings per PS batch

INJECTION SCHEME		General Info	Bunch Configuration	InjectionSequence	HEAD-ON COLLISIONS	LONG RANGE COLLISIONS B1	LONG RANGE COLLISIONS B2			
GRP :	ALL	name	order	ring	RFBucket	NbrBnches	BnchSpac[ns]	BnchInt[E9]	PartType	PS btchs
		B1 150ns1Batch8Bu bu1	1	RING_1	1	8	150	100	0	1
		B2 150ns1Batch8Bu bu1	2	RING_2	1	8	150	100	0	1
		B1 150ns2x225nsBatches8B...	3	RING_1	811	16	150	100	0	2
		B2 150ns2x225nsBatches8B...	4	RING_2	811	16	150	100	0	2
		B1 150ns3x225nsBatches8B...	5	RING_1	2131	24	150	100	0	3
		B2 150ns3x225nsBatches8B...	6	RING_2	2131	24	150	100	0	3
		B1 150ns4x225nsBatches8B...	7	RING_1	3961	32	150	100	0	4
		B2 150ns4x225nsBatches8B...	8	RING_2	3961	32	150	100	0	4
		B1 150ns2x225nsBatches8B...	9	RING_1	6301	16	150	100	0	2
		B2 150ns2x225nsBatches8B...	10	RING_2	6301	16	150	100	0	2

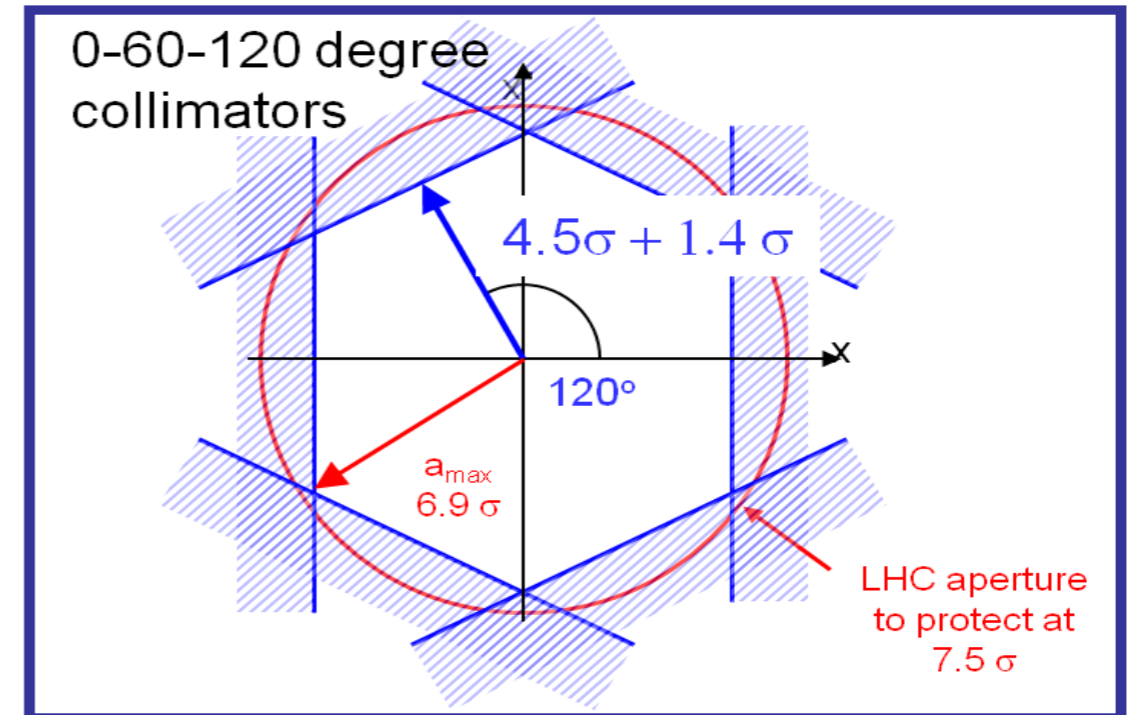
11:14:53 - head-on and long range collisions computed

- o Clearly a lot of changes in the CBCM, even hardware changes required
 - LHC MTG will have to talk to booster
 - Interface to LHC MTG for injection sequencer changes - our injection schemes will change...update of DB.
 - WE HAVE TO TEST THIS CAREFULLY. Period where LHC is already MASTER.

- o GENERIC single pass protection system → full phase space coverage required
 - Optics and space constraints → only 3 collimators (double jawed) per plane and per line
 - As close as possible to the LHC → at the end of the line

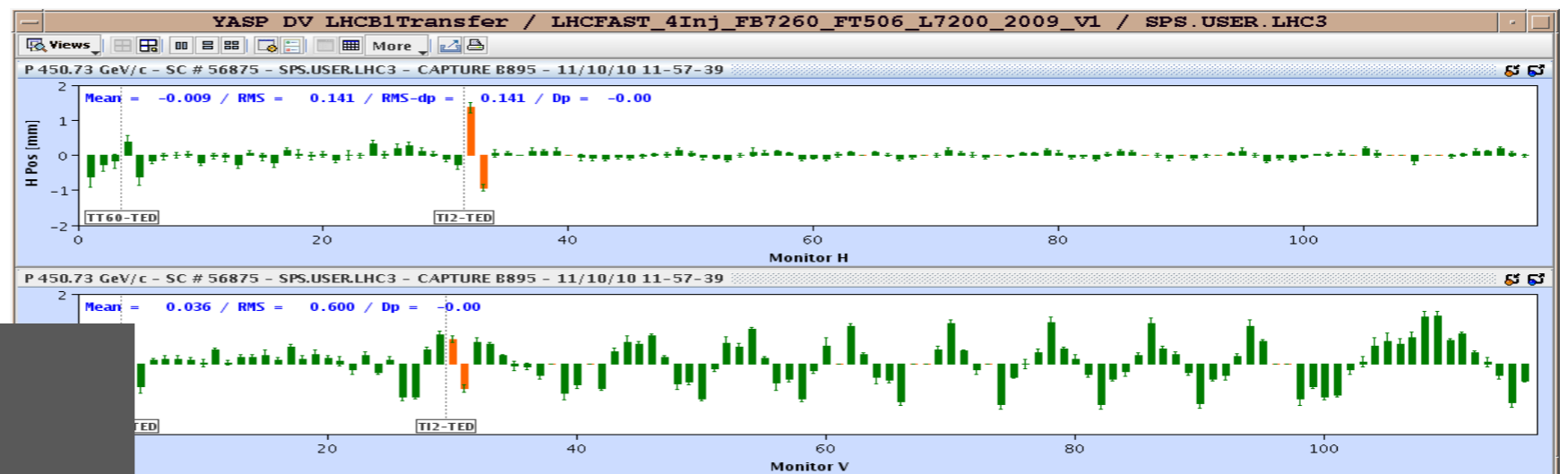


At the end of the line...and next to the LHC magnets with sensitive LHC BLMs



- o Setting depends on LHC aperture for INJECTED beam (not circulating beam)
 - There must be room for larger orbit excursions (before correction with low sensitivity) + injection oscillations
 - $4.5\sigma - 5\sigma$ setting for 7.5σ aperture: setting now 4.5σ
- o Aperture at injection was measured to be 10σ : on closed “corrected” orbit
- o LHC BLMs see showers from tight TCDIs: are we too CONSERVATIVE?

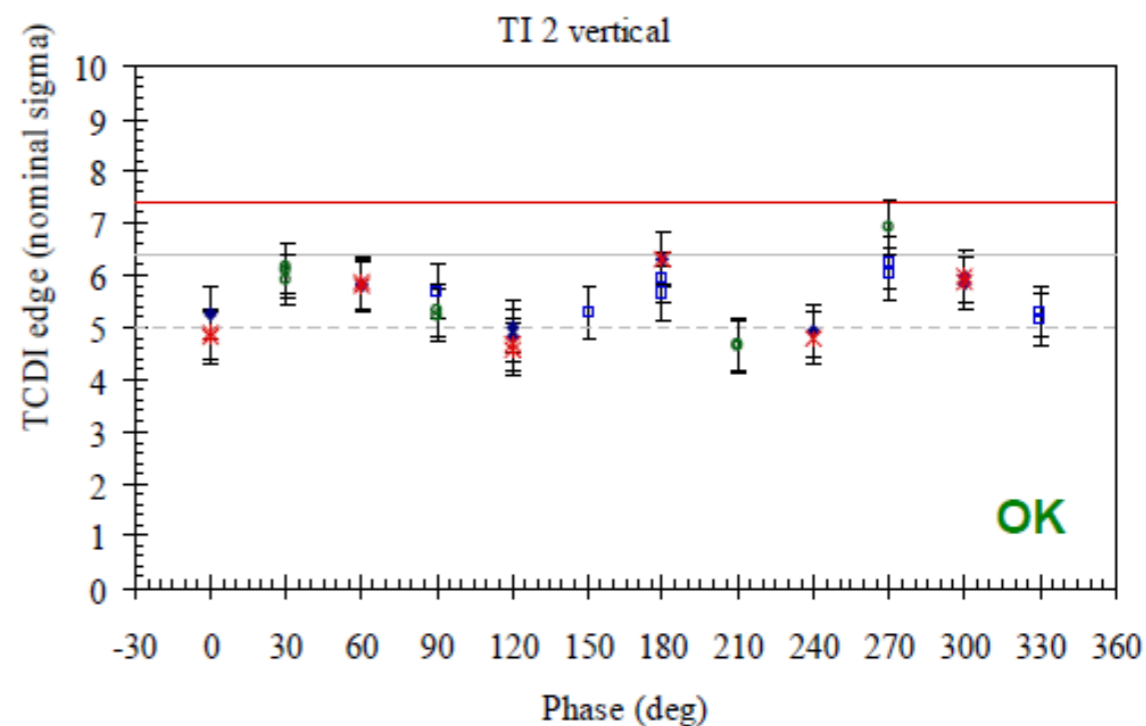
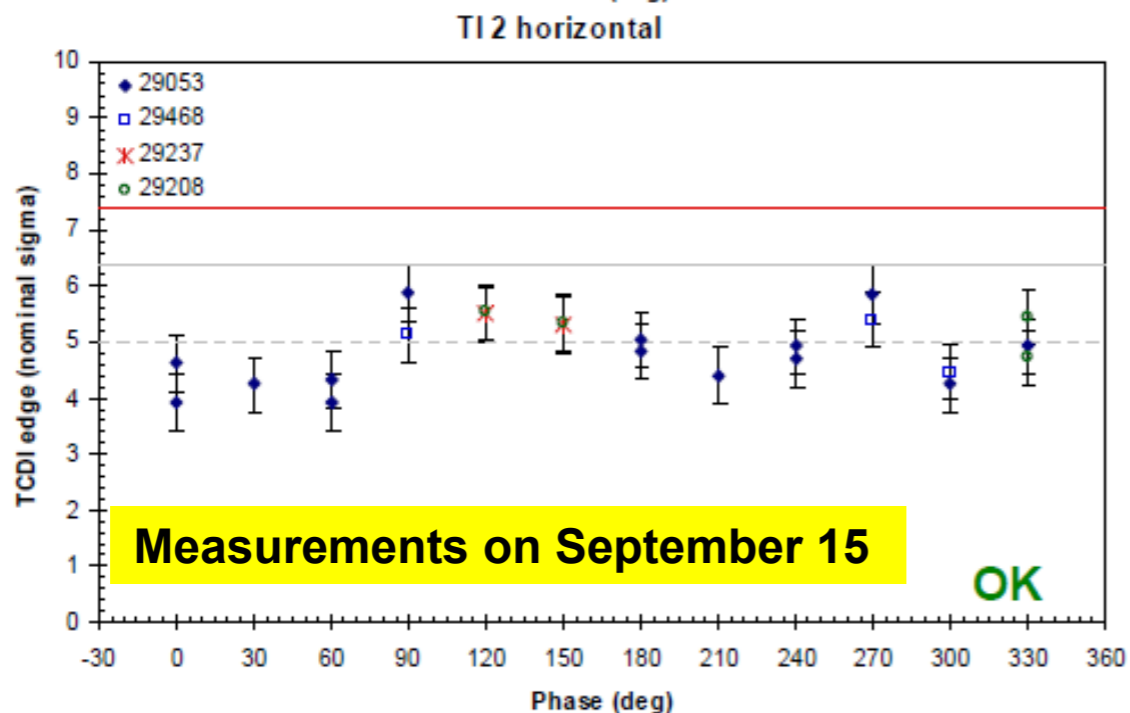
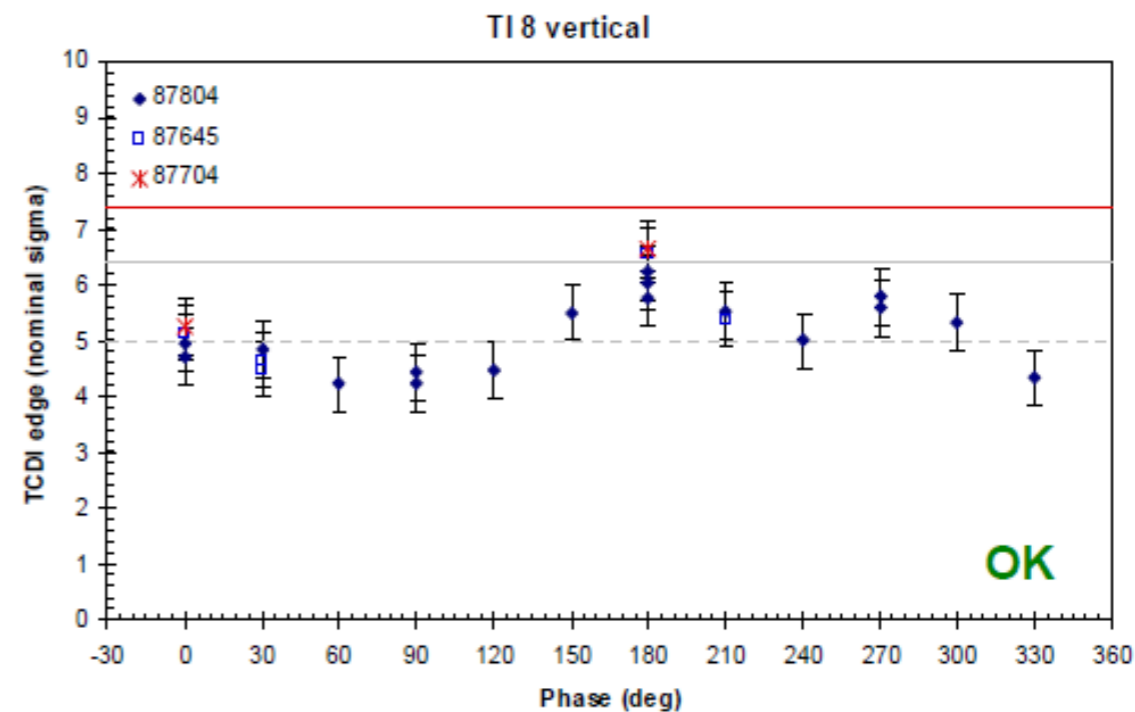
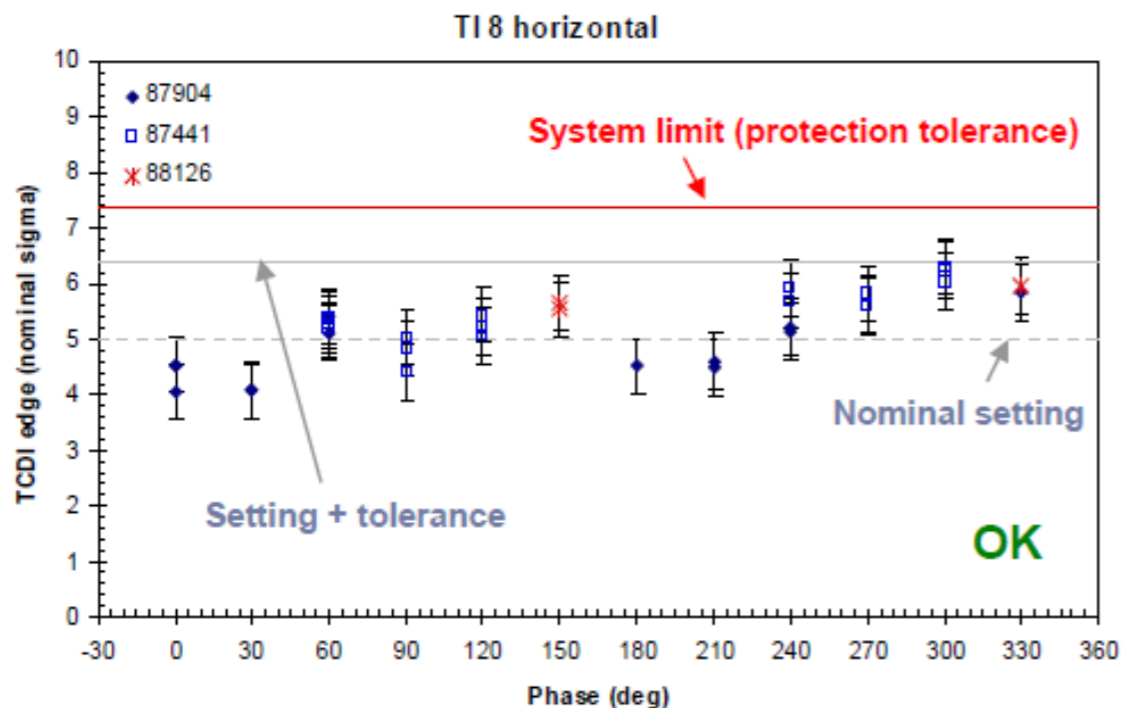
- o For orbit tolerances and injection oscillations
- o Orbit tolerances: **1 mm orbit bump limit** in SIS injection orbit interlock
- o Injection oscillations:
 - Can only correct after orbit corrections with high intensity
 - TCDIs are at the end of the line: correction is delicate, not many BPMs, do not want to move the trajectory at the TCDIs
 - Can allow for injection oscillations: “no” emittance growth: damper working well.
 - Something is changing (the lines are moving,...): can inject smoothly without having to continuously correct with a maximum of **1.5 – 2 mm injection oscillations**
- o If we want to keep these tolerances, the transfer line collimators have to be tight.



Example for injection oscillations – beam 1

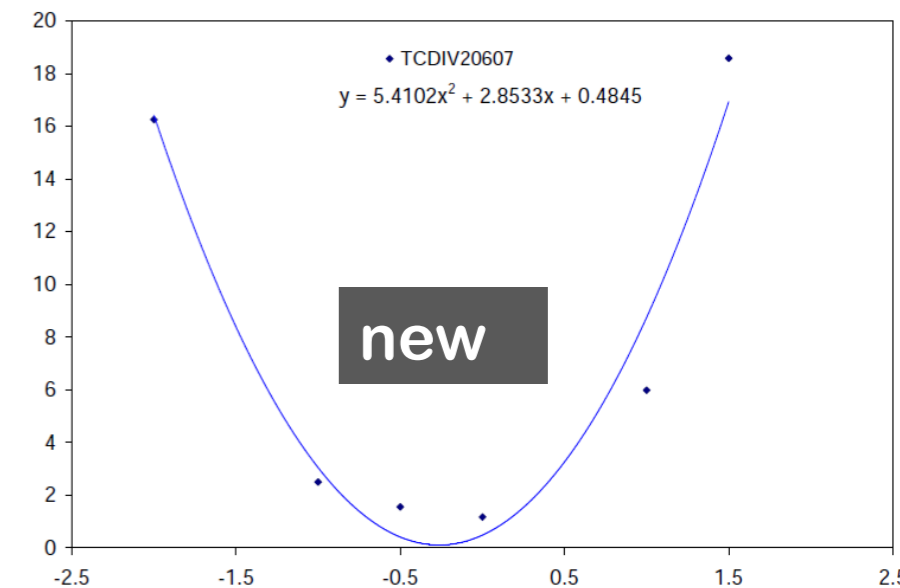
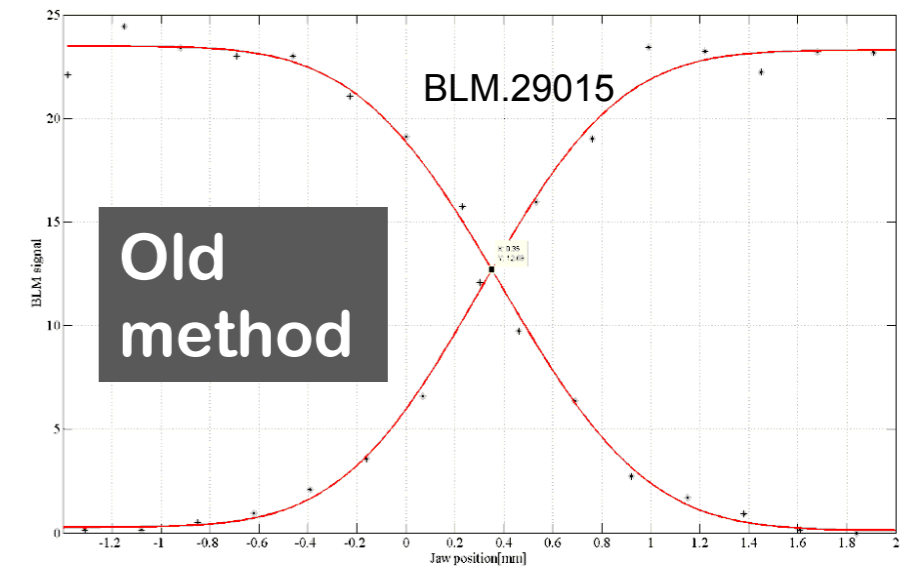
- Validation of phase space coverage (TCDIs @ 5σ): aperture scan with TCDIs.

- Aperture limit detection: loss of 5 mGy



- For that specific point in time: TCDIs provided full phase space coverage

- o Setting up: mid March 2009
 - Still old method
- o Adjustments from mid March to mid June
 - 1 – 2 TCDIs a couple of times (up to 800 um center changes)
- o Beginning of July: setting up for higher intensities
 - Different method: moving gap – **1 shift for both beams**
- o From then on – only adjustments to reduce losses when condition changed (increase of intensity, new pattern)
 - 1 – 2 TCDIs (up to 200 – 300 um)
 - No change even when going to 150 ns, to 50 ns, nor when moving to ions
- o Last big change: MSI aperture bottleneck
 - TCDIs not re-setup only moved according to trajectory interpolation (moved up to 1.2 mm)



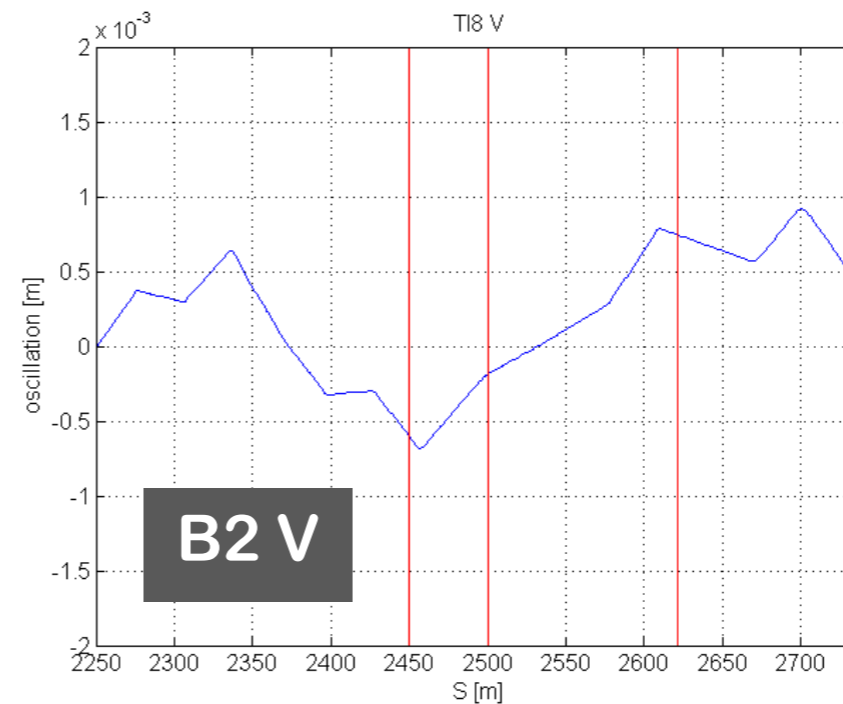
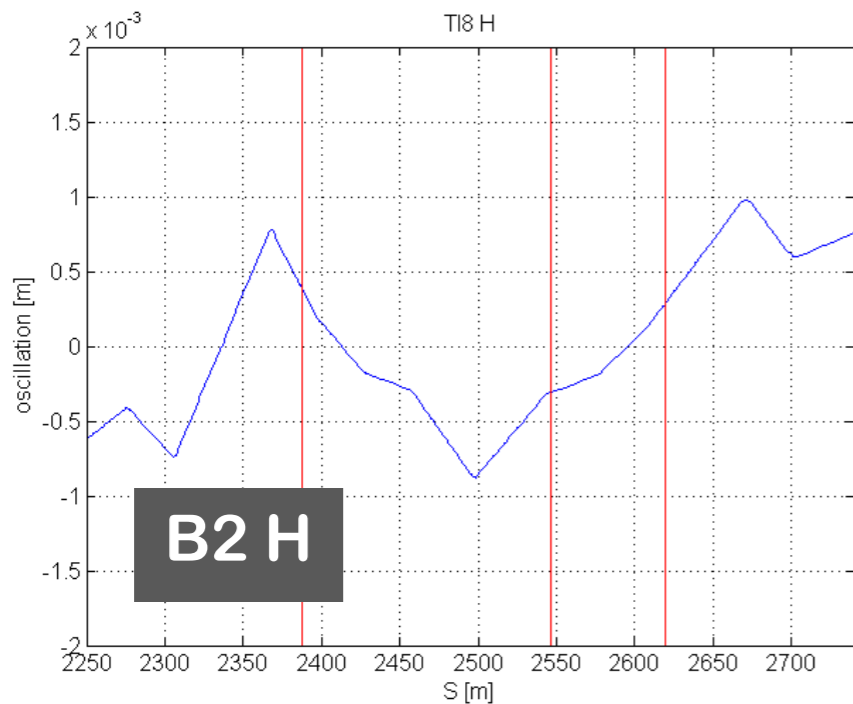
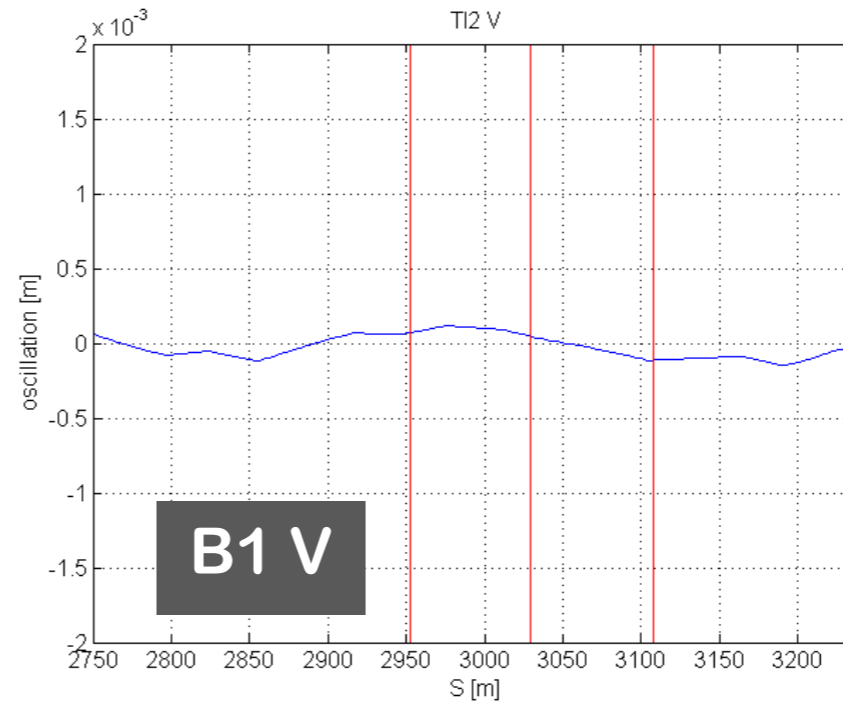
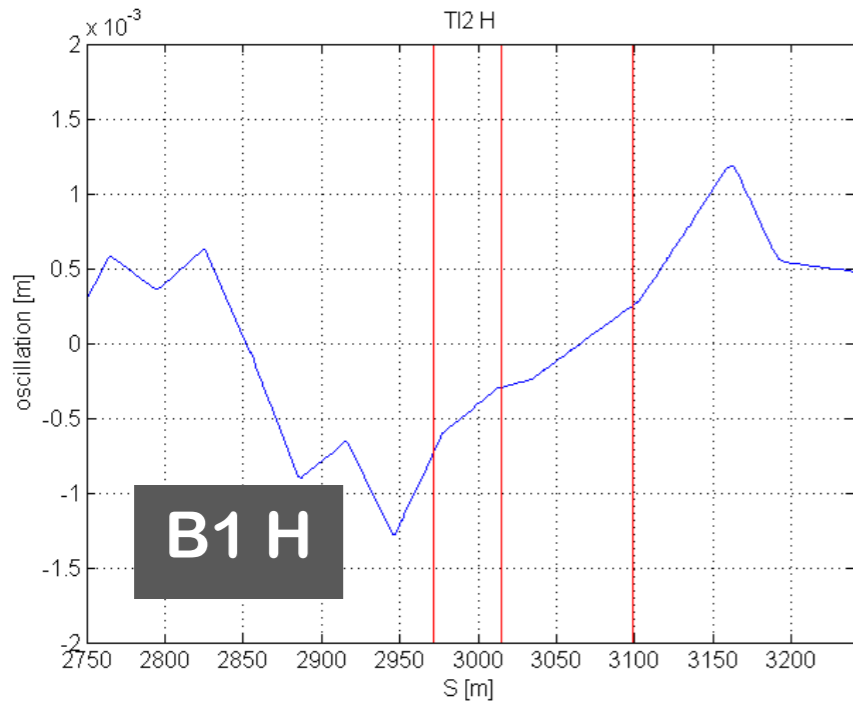
Always the same TCDIs:
 Beam 1: TCDIH.20950,
 TCDIH.29205
 Beam 2: TCDIH.87741

All horizontal

1. Inject pilot
 2. Inject **intermediate intensity**
 1. Will be enforced by the SIS: cannot inject high intensity without injecting intermediate
 3. New interlocking: SIS – IQC: additional IQC SIS interlock
 - If the injection oscillations latch, you can only reinject intermediate intensity
 - Need to make sure if high intensity already in, that in inj. osc. latch does not unnecessarily stop (possible “expert overwrite”)
 - OP corrects
 - Automatic removal of IQC inj. osc. latch if one injection good.
- o Should prepare and check:
- Prepare a special filling scheme with a couple of shots of intermediate intensity to correct
 - How much can OP correct?
 - Back to reference (different categories for ions and protons)
 - Still need to check whether need to close down possible correction range a little

By how much did we have to correct?

- o Steering triggered by losses during injection/injection oscillations
- o Total correction applied during 150 ns running: (start Sep. '09 – end Oct. '09)



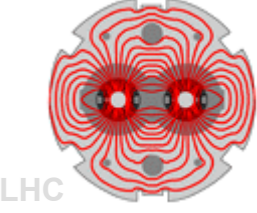
Corrections moved beams $\sim 1 \sigma$ at TCDIs

(To hopefully center the trajectory again)

- o Did not check the centering each time...



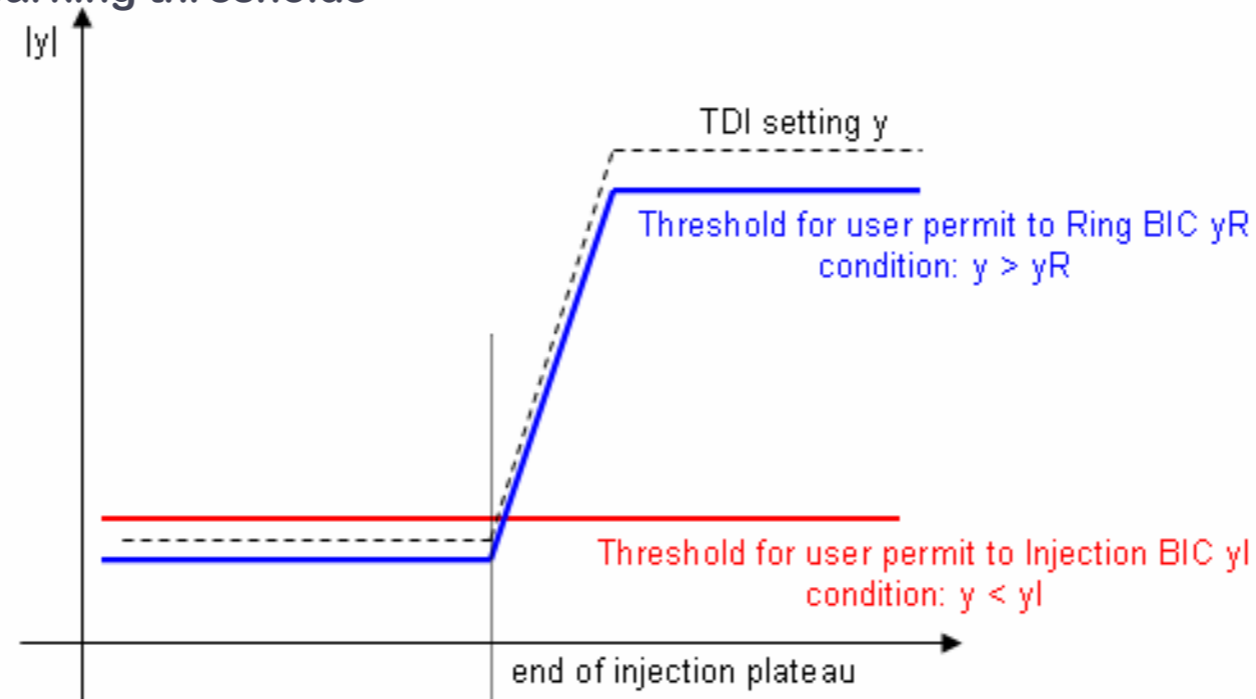
Beam onto TDI



- o On several occasions beam was accidentally put 24b and 32b onto TDIs... protection is really being used and essential!
- o Reasons for the accidents
 - Abort gap window moved – not understood. Systematic checking of the timing (IPOC?)
 - Abort gap keeper not respected in filling scheme (was caught by SIS but overridden – make unmaskable?)
 -
- o Question by the filling scheme makers:
 - Abort gap keeper window flexibility?
 - Reduce if run the whole year with fewer than 288 bunch 25 ns injections?
 - No – would need additional check to not inject 8 us batch.

- o Threshold management.
 - Having to load parking thresholds
 - missing energy gaps for TDIs

- o Shutdown improvements:
 - For sure: Energy gaps for TDIs
 - Still under discussion with Collimation (needs a lot of extra testing):
 - ❑ Remove movement blocking when going across thresholds entirely for TCDIs
 - ❑ No more parking thresholds are required. No more threshold change for driving them to parking.
 - ❑ Remove movement blocking when going across OUTER thresholds for TDIs and TCLIs.
 - ❑ Special parking thresholds

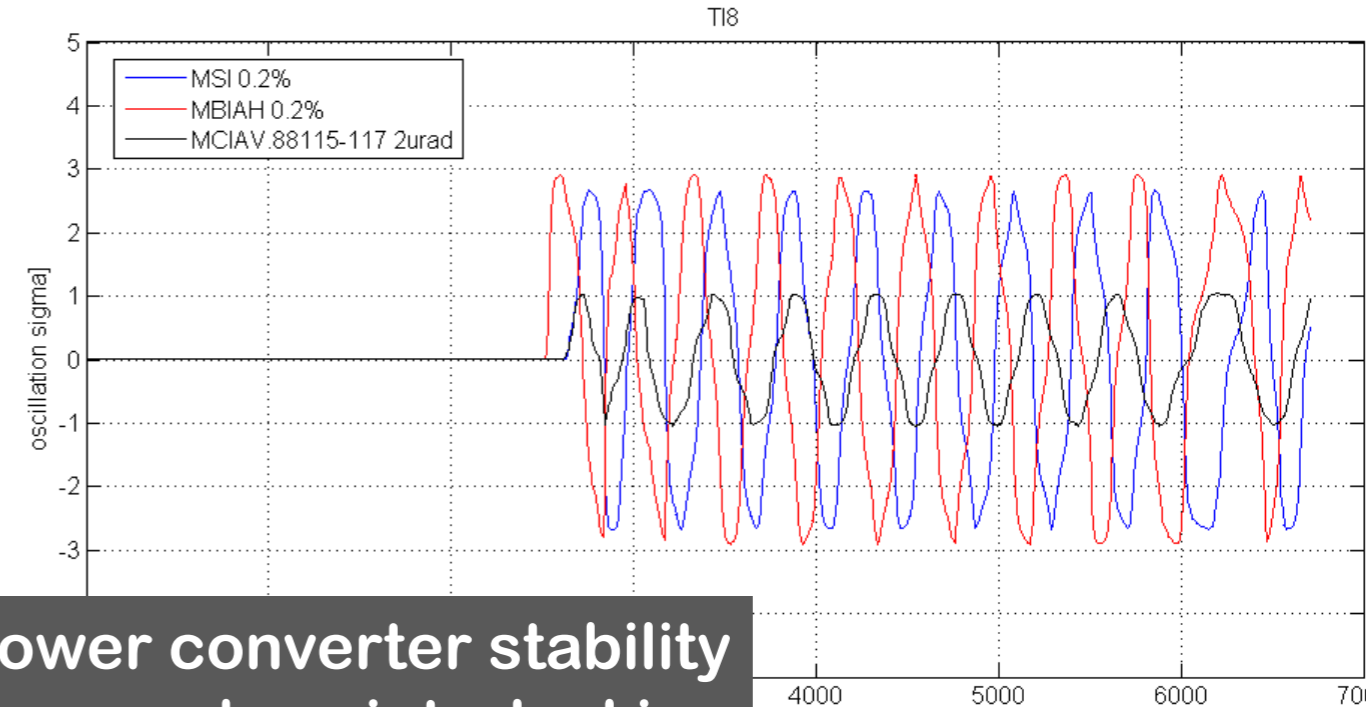
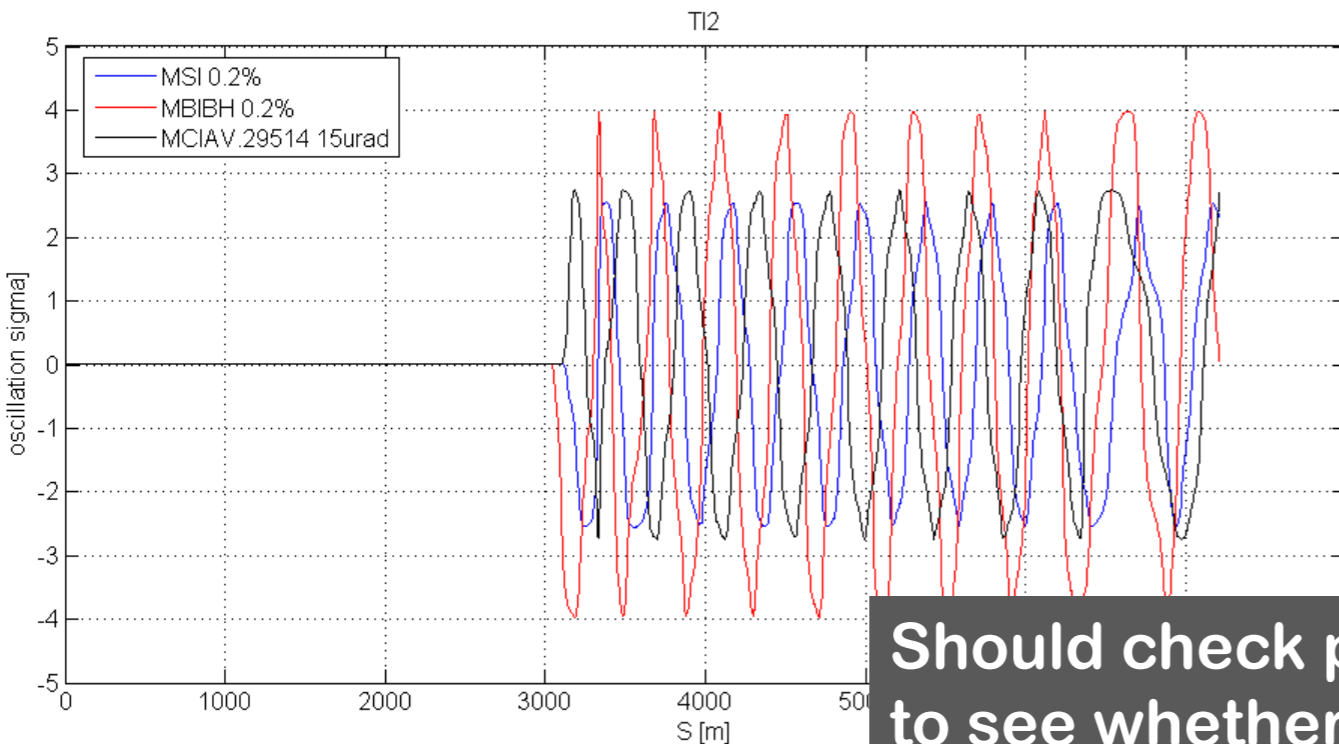


- o Timing synchronization: GPS
 - SAFE in all cases: beam goes on TDI
 - Improvement will come after shutdown: injection not possible if GPS off
- o Circuits at the end of the line
 - Circuits within or after TCDIs

T18	
MBIAH	FMCM
3 x MCI AV	-
MCIAH, MCI AV	-
MSI	FMCM

“slow”: in case of trip
185 ms to reach 10σ

T12	
MBIBH	FMCM
MCI AV	-
MSI	FMCM



Should check power converter stability to see whether can reduce interlocking tolerance.

- o **Overinjection:**
 - 2 options for next year
- o **Proposal:**
 - Keep pilot as part of the filling scheme.
 - Overinjection: Injection scheme editor defines per filling scheme “good” place of pilot
 - Aim: do not kick out pilot if beam does not come.

- o **Injection oscillation at each injection are essential:**
 - Coexistence with MD is an issue.
 - New concentrated property for a couple of crates only for injection oscillations: will be set by injection sequencer
 - Normal capture concentrator: can be used on the other crates to study injections

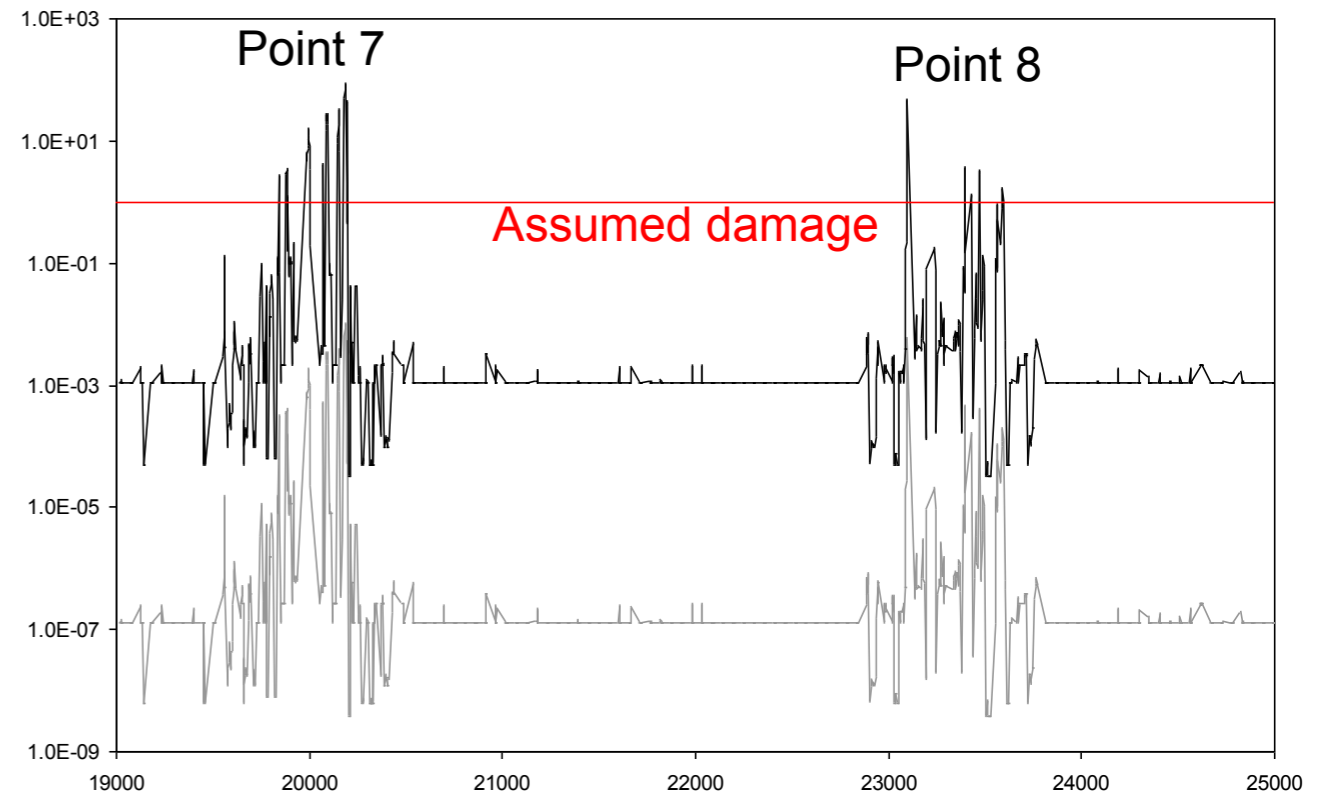
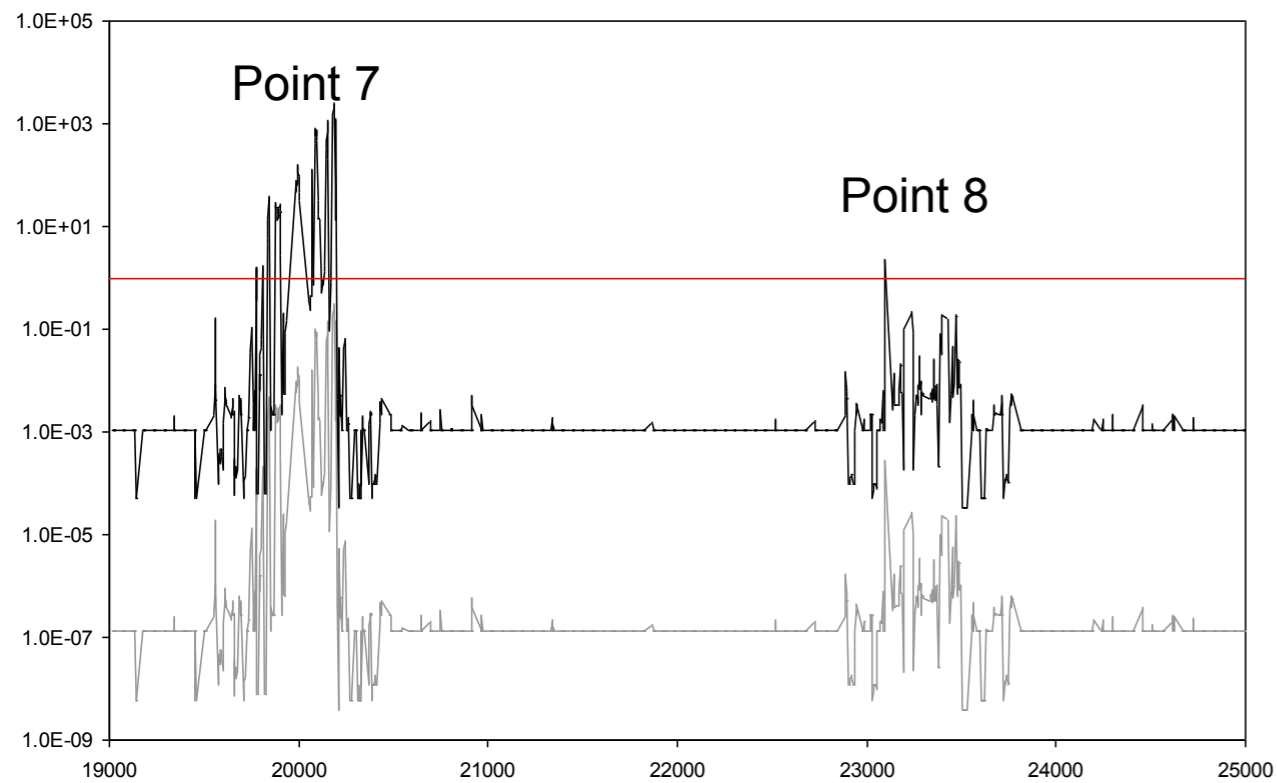
- o Injection protection is fully operational.
 - and working well: all problems so far caught, TCDIs at 4.5σ – no problem
 - Saved LHC from damage already several times (beams onto TDIs)

- o Are we taking it seriously?
 - Most of it: yes. Injection interlocking etc. looks good.
 - Injection oscillations + orbit: not fully yet: will come next year
 - Has been too easy to put full injected batch onto TDI...improve this

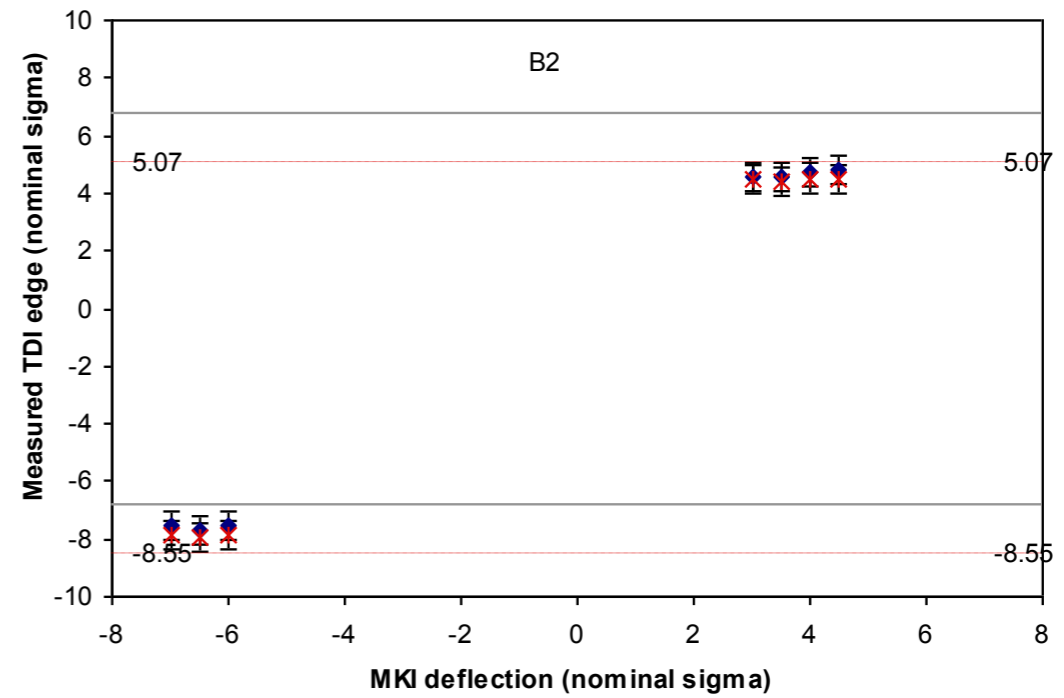
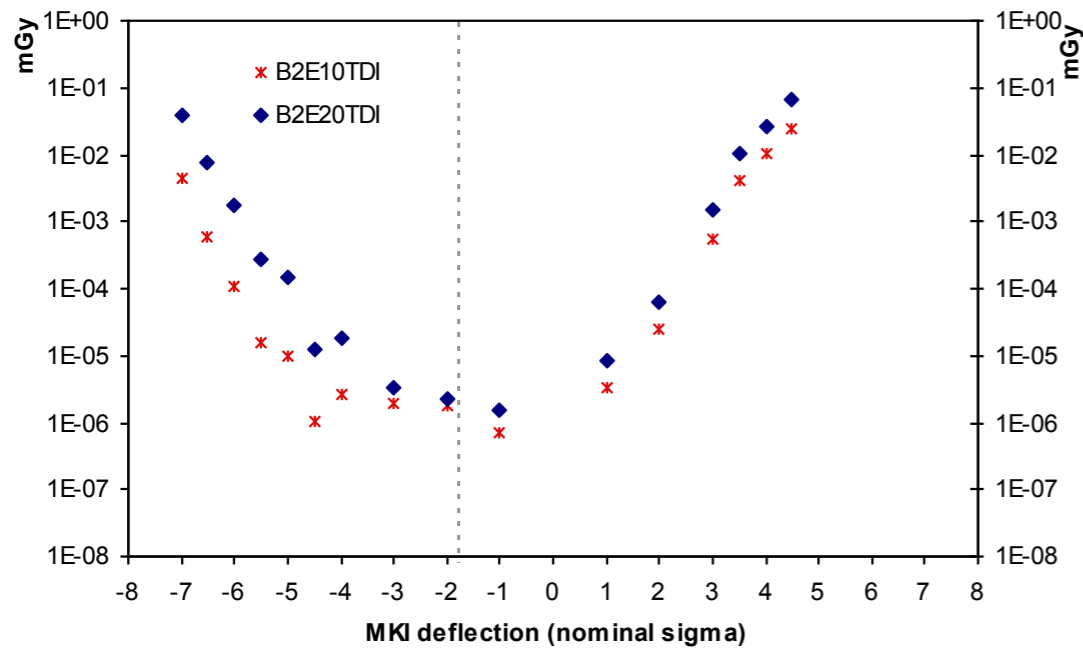
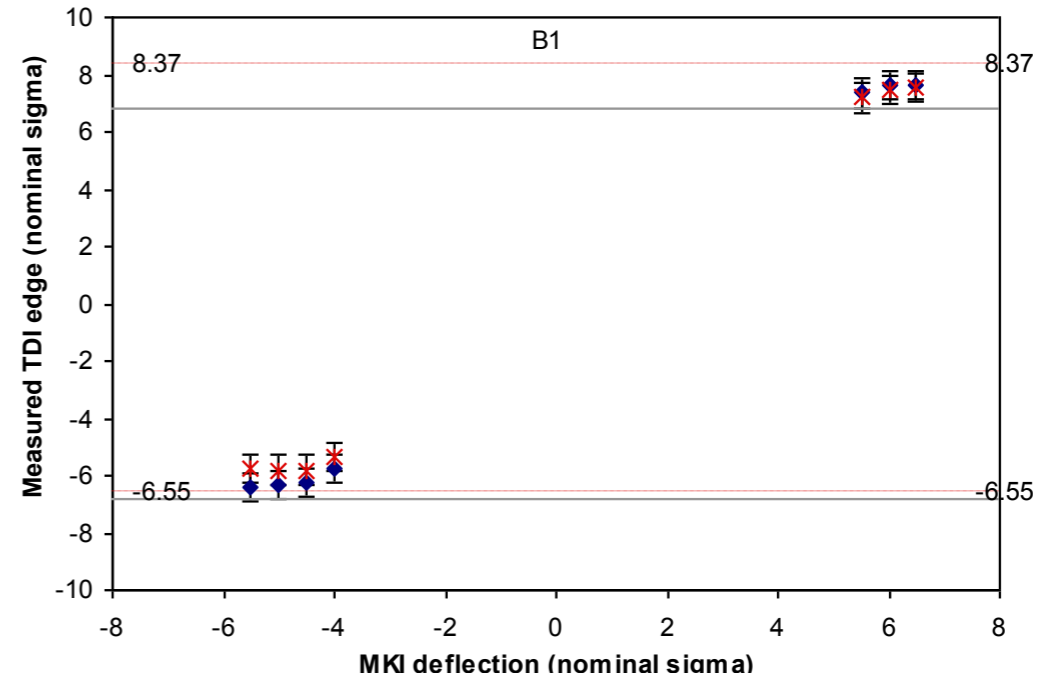
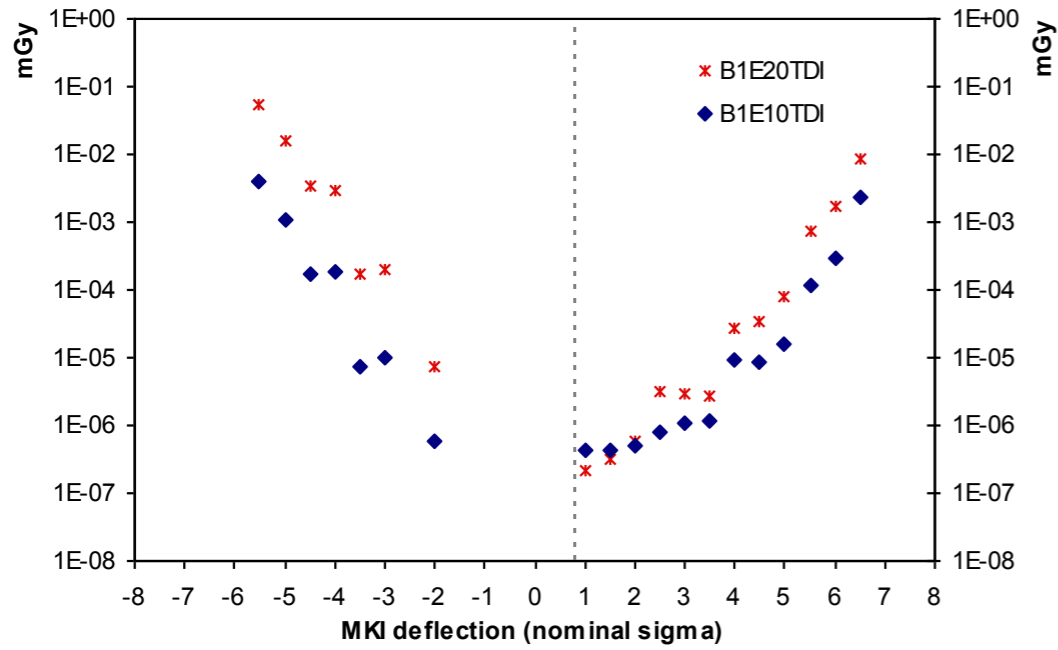
- o How can we make it safer:
 - Concept of intermediate intensity + injection oscillation interlock
 - Threshold management of injection protection
 - Timing system fix for GPS problems
 - Tightening up operational settings tolerances on MKI
 - Checks in InjectionSchemeEditor for filling patterns vs AGK

RESERVED SLIDES

- o Are TCDIs protecting at required amplitude?
 - 7.5 s oscillation at a chosen phase
 - Measurement done with pilot. Result scaled to $288 \times 1.15e+11$ p+ and compared to “assumed” damage limit



- Protection OK. Analysis still not finished.



	B1 (sigma)	B2 (sigma)
Centre	0.85	-1.75
Gap	13.53	12.35
Protect +	8.37	5.07
Protect -	-6.55	-8.55
Protect if centred	7.46	6.81
System protection	8.37	8.55

- o Have to work on understanding stability.
- o See also Wolfgang's talk: losses transverse and long

- o Clearly: have to keep longitudinal and transverse sizes under control
 - Just important for losses at TCDI, not for phase space coverage

- o Why different trajectories?
 - Different energy? From the SPS...
 - Does place of LHC cycle in SPS supercycle have an effect? MDs to plan...

Example: Diff. -
Trajectory for ions
one Nov. 23

Source for
oscillation not
clear.

