5^{th} EVIAN WORKSHOP, 2-4 JUNE 2014

Two Beam Effects

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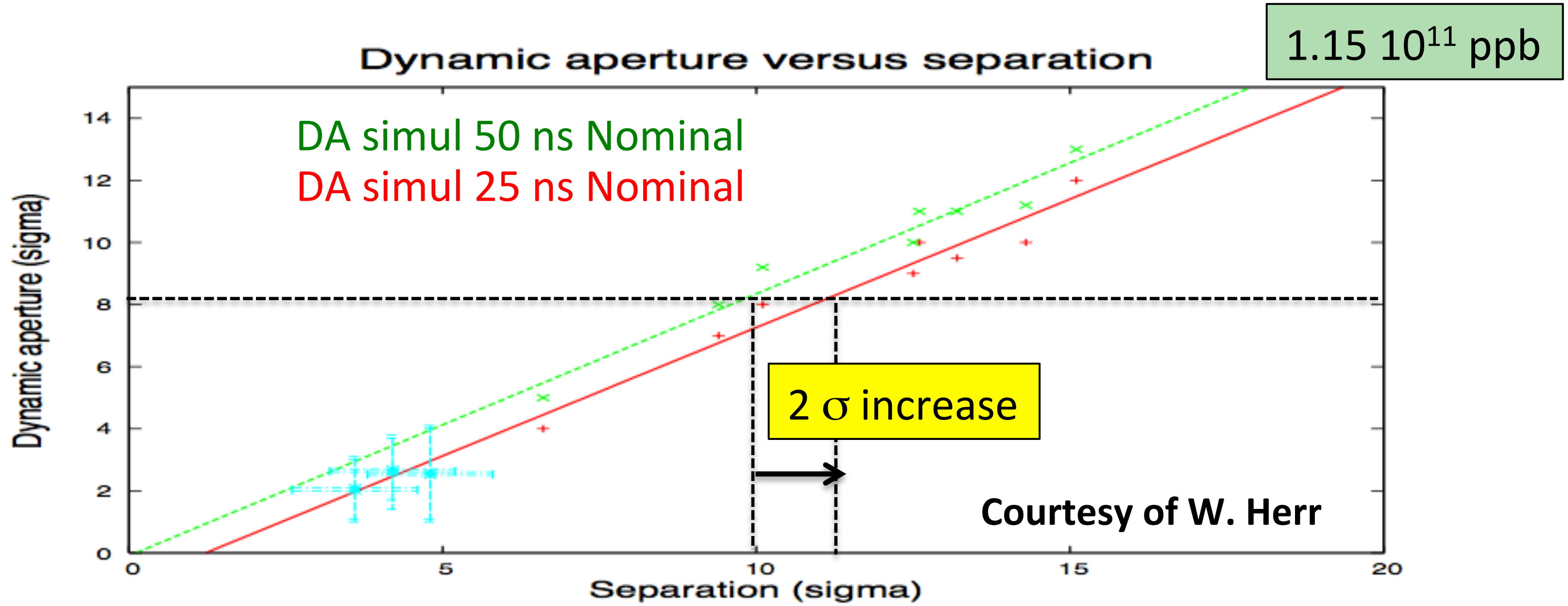
Outlook

- Incoherent Beam-Beam
  - Long ranges MDs and scaling laws
  - Beam-beam DA 2012 versus 2015: crossing angles
- Instabilities 2012
  - End of squeeze
  - Adjust Instabilities
  - IP8 Snowflakes
- Summary and possible scenarios

From 50ns to 25 we need 2 more sigma in separation: scaling from 2010-2011-2012 experience



We scale from 2011 always using simulations in relative.

This doesn't exclude reduced X-angle.

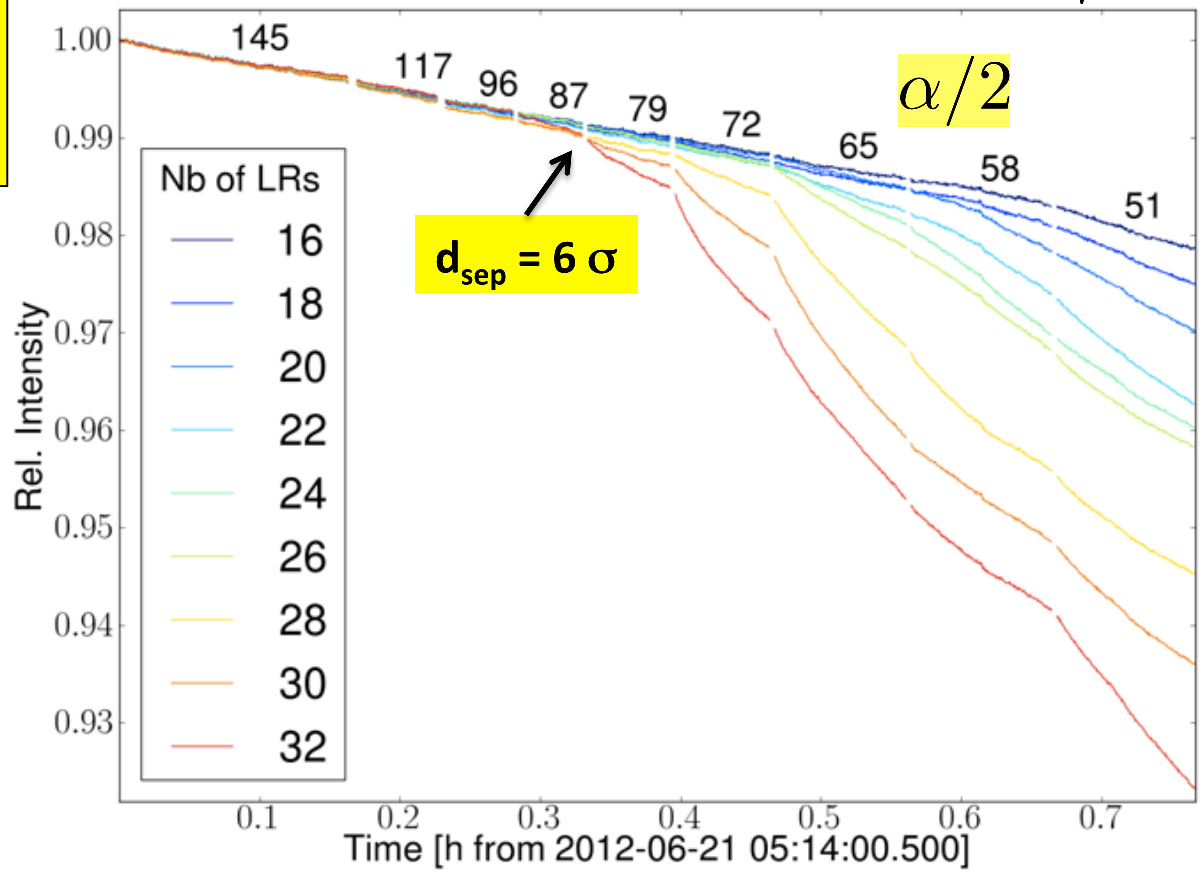
We start as in 2012 solid and experimentally robust then we push down as close as possible to the limit (6-5 σ DA)?

BB LR experiments 2011-2012:

Beam parameters:
N_b = 1.6 e11 ppb
ε = 2.2 μm
IP1 crossing angle
Q' = 2 units

Beam-Beam separation at first LR

$$d_{sep} = \alpha \cdot \sqrt{\frac{\gamma \cdot \beta^*}{\epsilon}}$$



- **Difficult to relate to machine configuration the absolute value of DA!**
- **50 ns beams confirmed scaling laws for β^*, N_p and defined lower limits!**
- **25 ns test not conclusive, difficult emittance estimates, big error bars!**

Beam Beam Long-Range experiments 2011-2012:

Beam-Beam separation at first LR

$$d_{sep} = \alpha \cdot \sqrt{\frac{\gamma \cdot \beta^*}{\epsilon}}$$

Spacing (ns)	β* (m)	N_b	α (μrad)	d_{sep} (losses)
50	1.5	1.2 10^{11}	240	5 +/- 0.5 σ
50	1.5	1.2 10^{11}	240	5 +/- 0.5 σ
50	0.6	1.2 10^{11}	290	5 +/- 0.5 σ
50	0.6	1.6 10^{11}	290	6 +/- 0.5 σ
25	1.0	1.0 10^{11}	290	6.5 +/- 1 σ

d_{sep} counts

1 σ loss for int increase

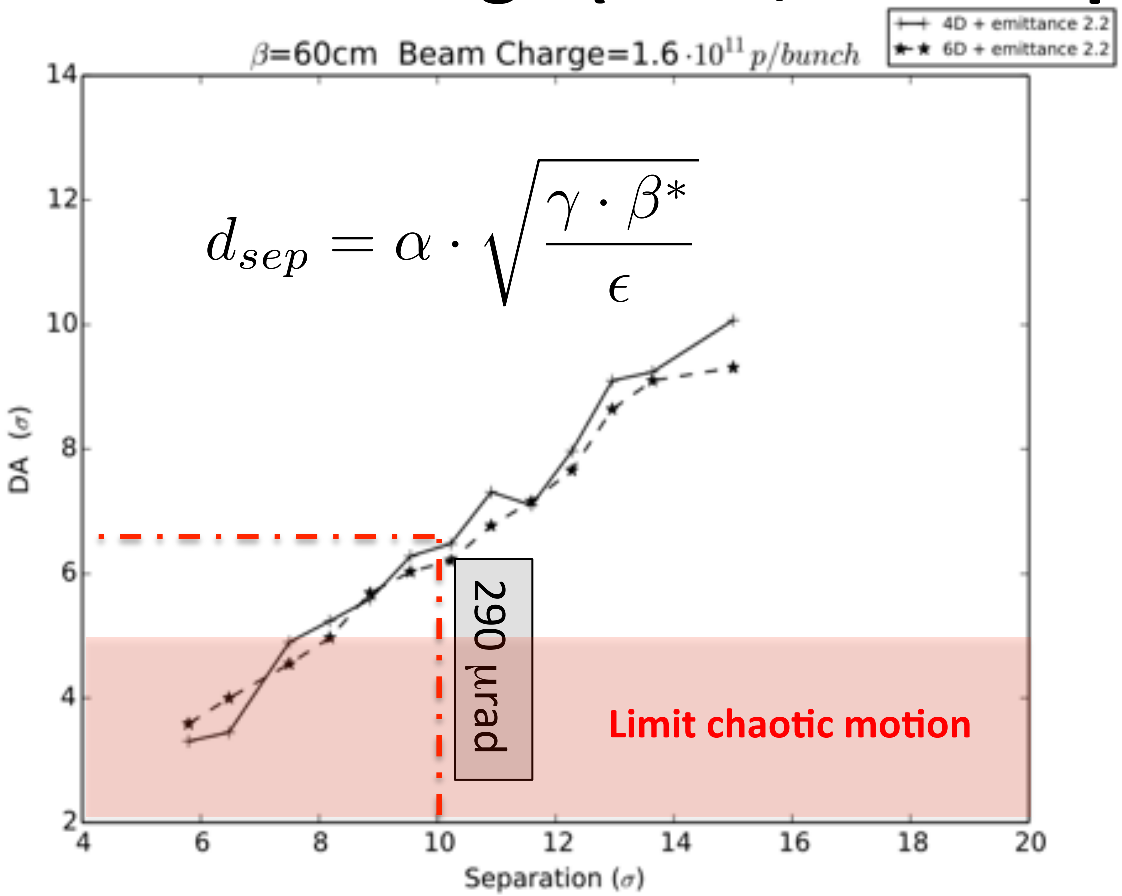
2 σ loss 50 → 25 ns

Onset of losses (limit of chaotic motion) identified for several cases but we do not have a robust experience with 25 ns:

- **50 ns beam well understood, scaling laws confirmed with β* and N_p**
- **2012 trial with 25 ns: 12 σ separation for 1e11 ppb 2.5 μm emittances**
- **Long Range MD not conclusive!**

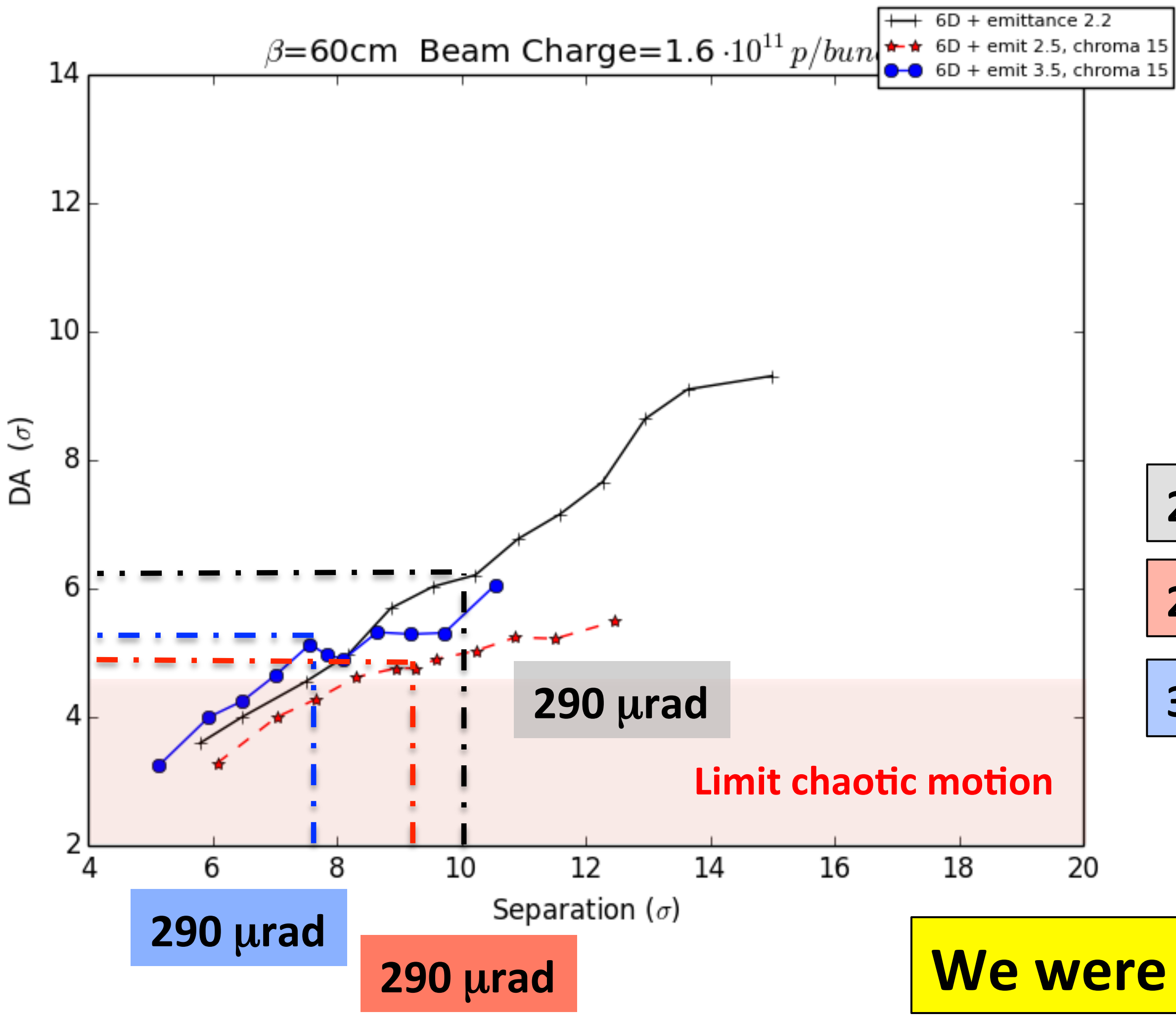
What have we seen in operation with 50 ns beams?

Before Middle Year Change (Q'=2, no octupoles…)



- Always **better DA than the LHC design Report "THANKS" to offset leveling in IP8**
- **Lower limit** around 4-5 σ DA
- **6.5-7 σ DA showed to be very good in 2012** before MYC!
- Best fills of the year in terms of integrated Luminosity!

After Middle Year Change (oct polarity, Q',…)



Beam parameters:
N_b = 1.6/1.7 e11 ppb
ε = 2.5-3.5 µm
IP8 leveled offset = 2.5 σ
Q' = **15** units

2.2 µm beams → d_{sep} = 10 σ

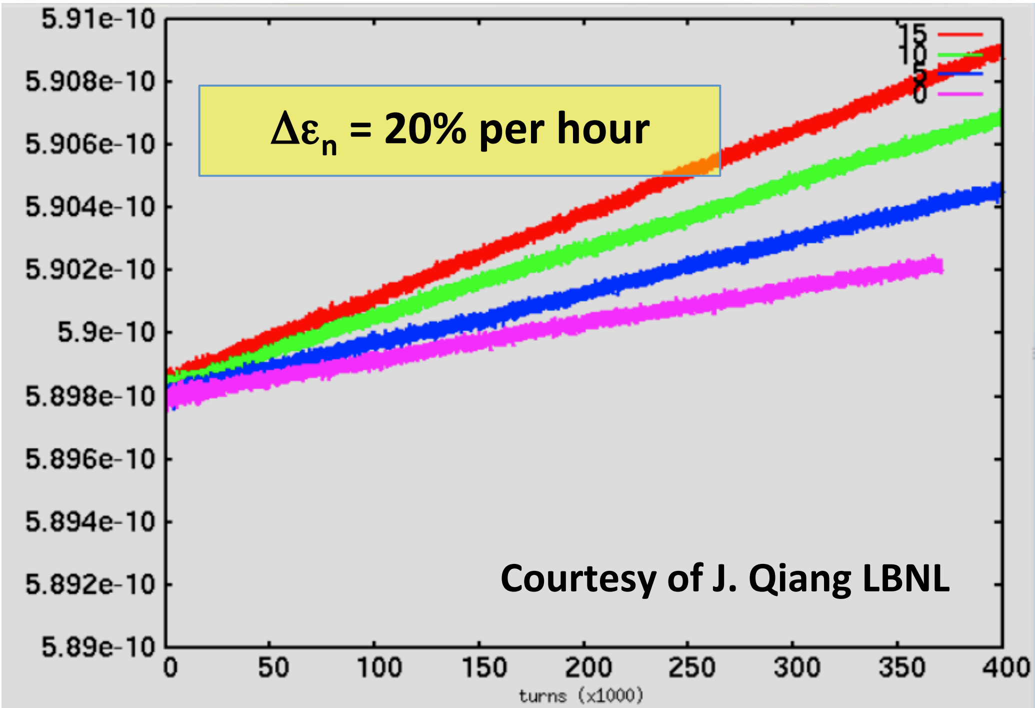
2.5 µm beams → d_{sep} = 9.2 σ

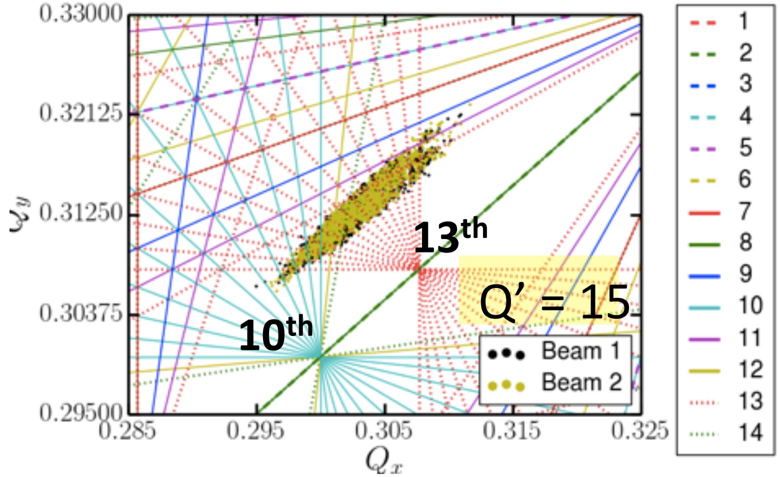
3.8 µm beams → d_{sep} = 7.8 σ

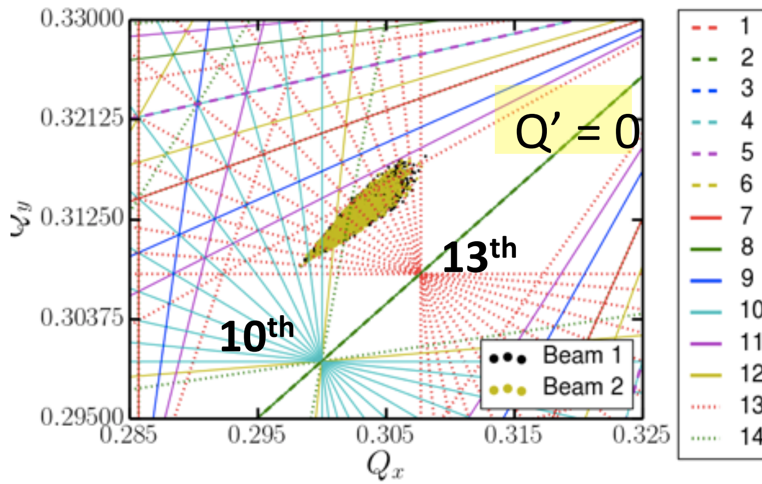
We were very close to the limit!

- **High Chromaticity has very BAD impact on Dynamic Aperture!**
- **Incoherent beam-beam might justify the lumi loss in 2012 after MYC**

Head-on: slow emittance increase

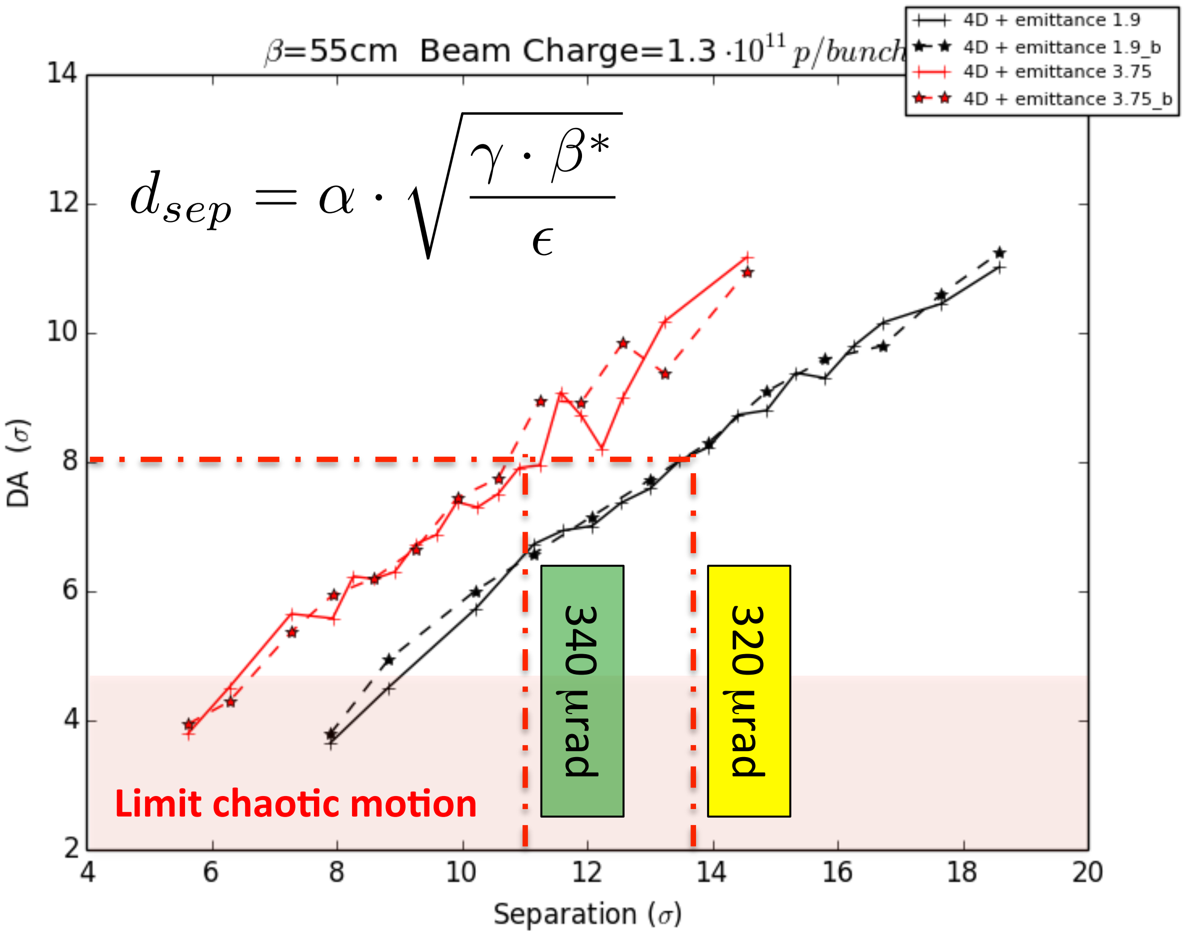






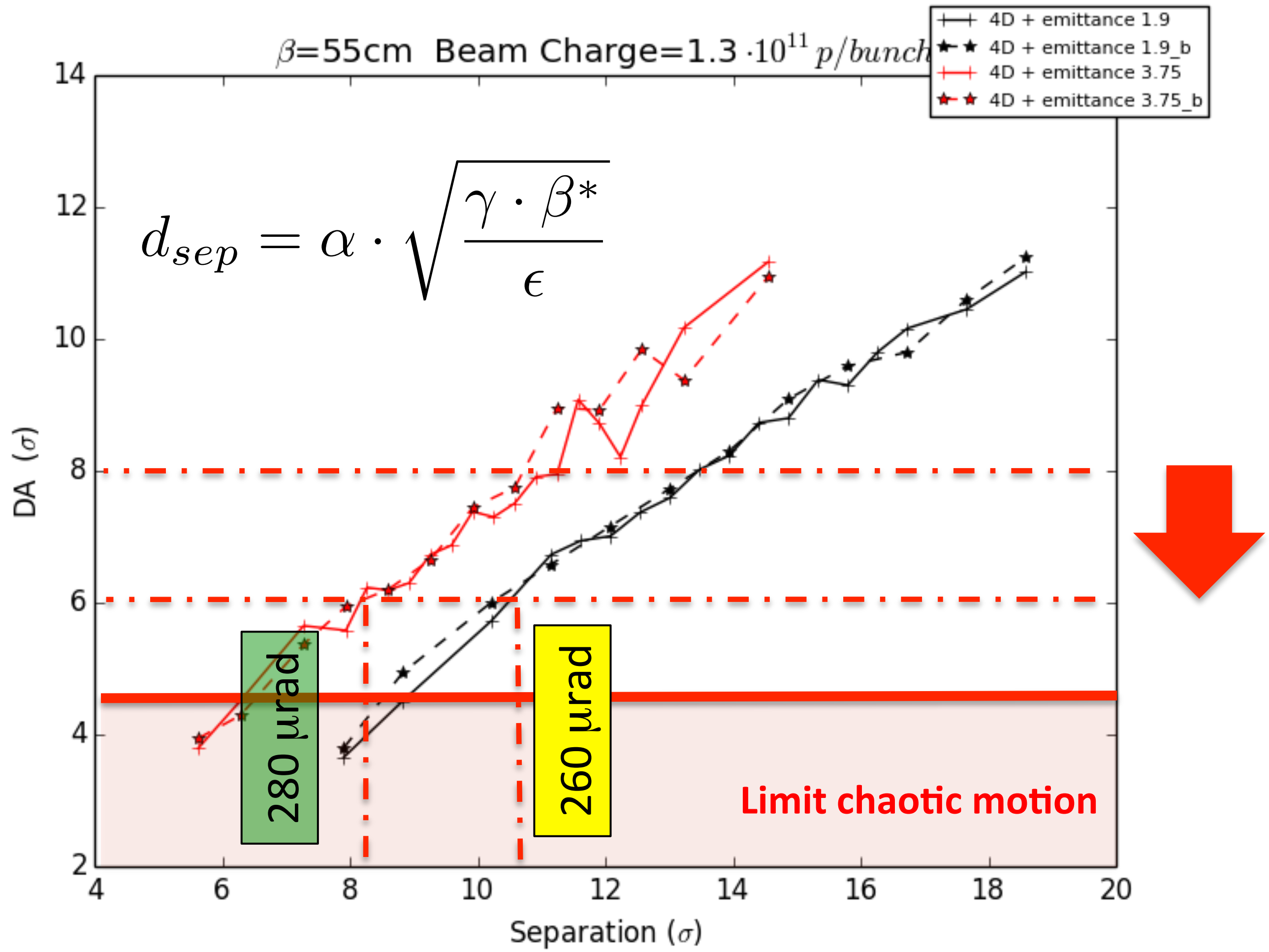
- Chromaticity creates larger detuning of particles
- Simulations show a slow but relevant emittance blow-up due to head-on
- This will require a tune scan to optimize Head-on collisions first!

2015 relaxed star-up: crossing angle



- Start with relaxed Long range encounters, we have margin for set-up and "exploration" of Long Range effects with 120 encounters (60 LR in 2012).
- Evaluate Head-on effect Optimization of working points.
- <u>Long range MD to define limit of chaotic motion</u>

2015 reduced crossing angle: to the limit!



From Long Range MD in early stage of commissioning:

- **Identify the Limit of chaotic motion**
- **Evaluate the impact of IP8 leveling (offset? β*?)**
- **Reduce in second step the crossing angle to reach the lower boundary**

Summary of crossing angles IP1&5

Push in second stage when:
- lower limit identified
- Instablities under control
- Beam parameter and set-up defined

Start-up

	Crossing angle	BB Separation	Crossing angle	BB Separation
Standard LHC (3.75 μm, 1.3e11 ppb max)	**340 μrad**	**11 σ**	**255 μrad**	**8 σ**
BCMS (1.9 μm,1.3 e11 ppb max	**320 μrad**	**13.5 σ**	**245 μrad**	**11 σ**

8 σ Dynamic Aperture

6 σ Dynamic Aperture

Other pros considerations:
- **To cure instabilities might require larger angles!**
- **Keep LR weak to optimize Head-on first, tune scan.**
- **BB Orbit effects weaker (lower than 0.1 σ) if collide&squeeze needed**

IP2 and IP8 should stay in the shadow of the main IPs, will need detailed consideration depending on the operation (b* lev? Offset?)

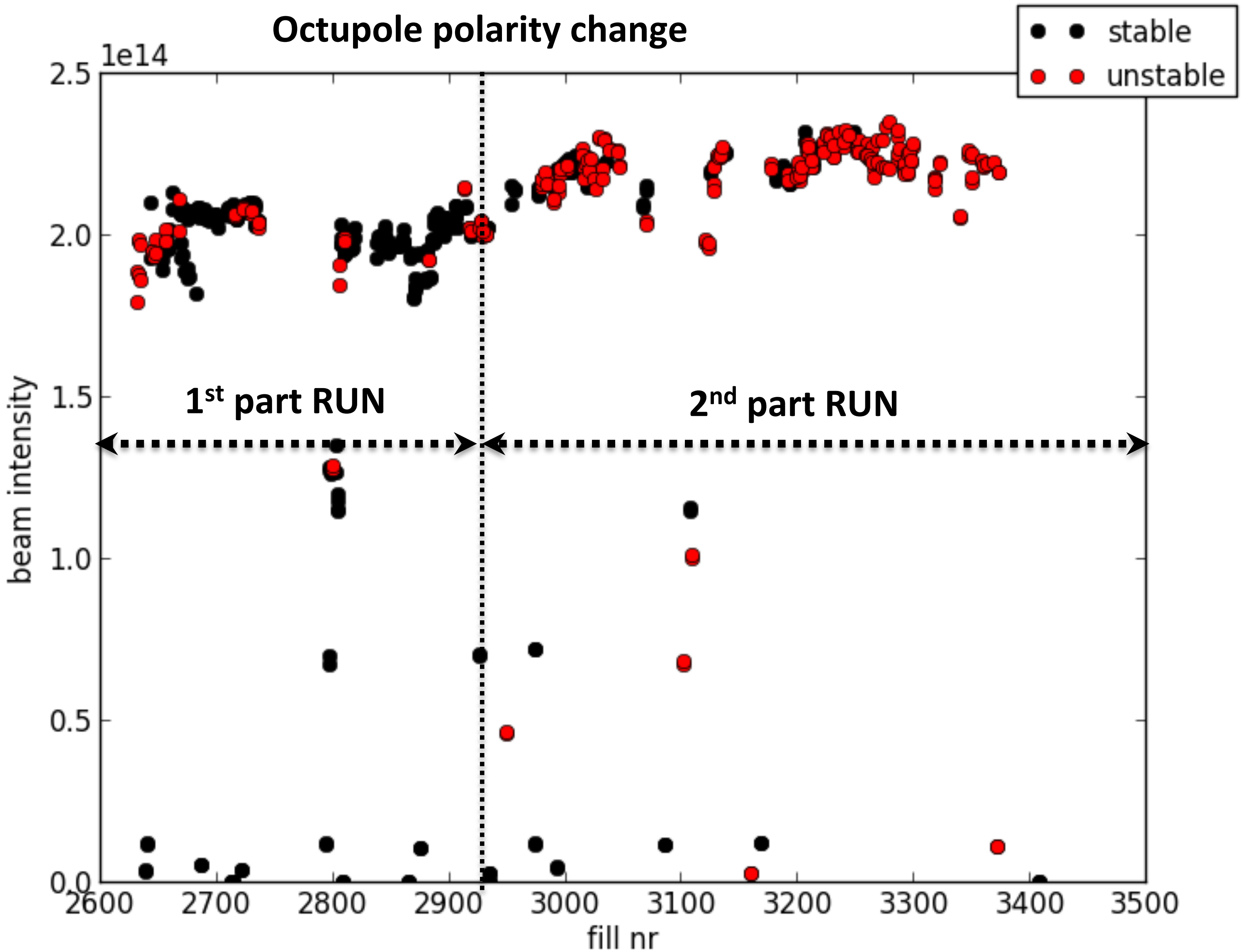
Outlook

- Incoherent Beam-Beam
  - Long ranges MDs and scaling laws
  - Beam-beam DA 2012 versus 2015: crossing angles

- Beam-Beam & Instabilities 2012 understanding and 2015 expectations:
  - End of squeeze
  - Adjust Instabilities
  - IP8 Snowflakes

- Summary and possible scenarios

End of Squeeze instabilities 2012

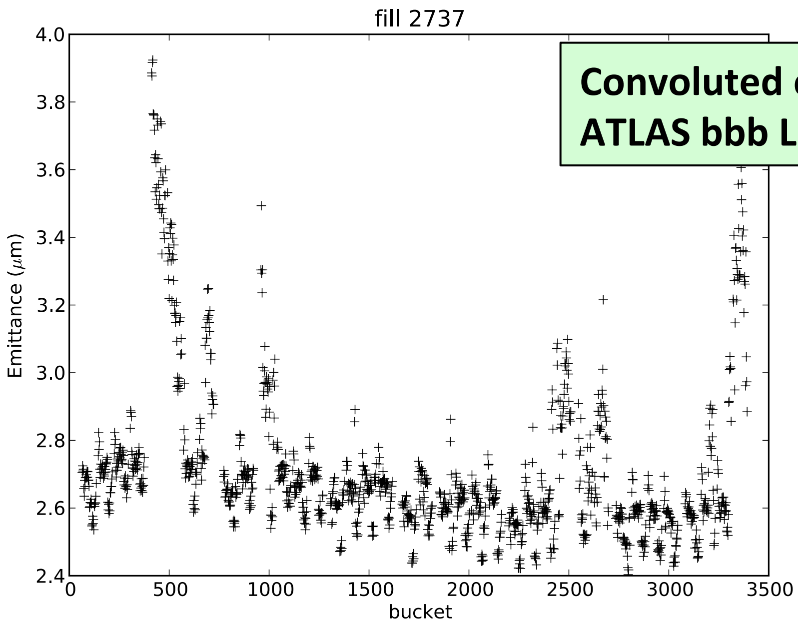


Before MYC

After MYC

Before MYC

- **Negative Landau Oct Polarity**
- **Q' = 2 units**

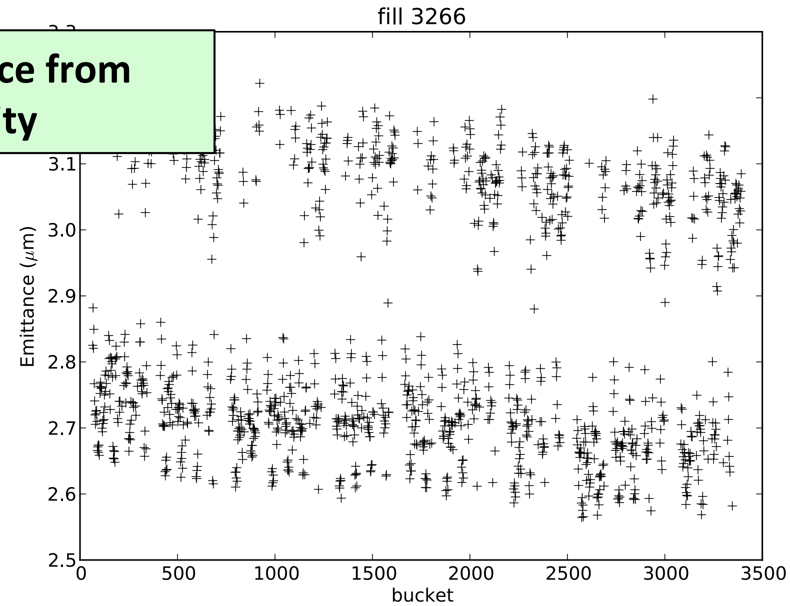


Convoluted emittance from ATLAS bbb Luminosity

- **Beam 1/2 plane V/H**
- **Coherent oscillations of selective bunches (BBQ, ADT)**
- **Sharpe Intensity losses (up to 70-60%)**
- **Selective emittance blow-up**
- **Not clear pattern**

After MYC

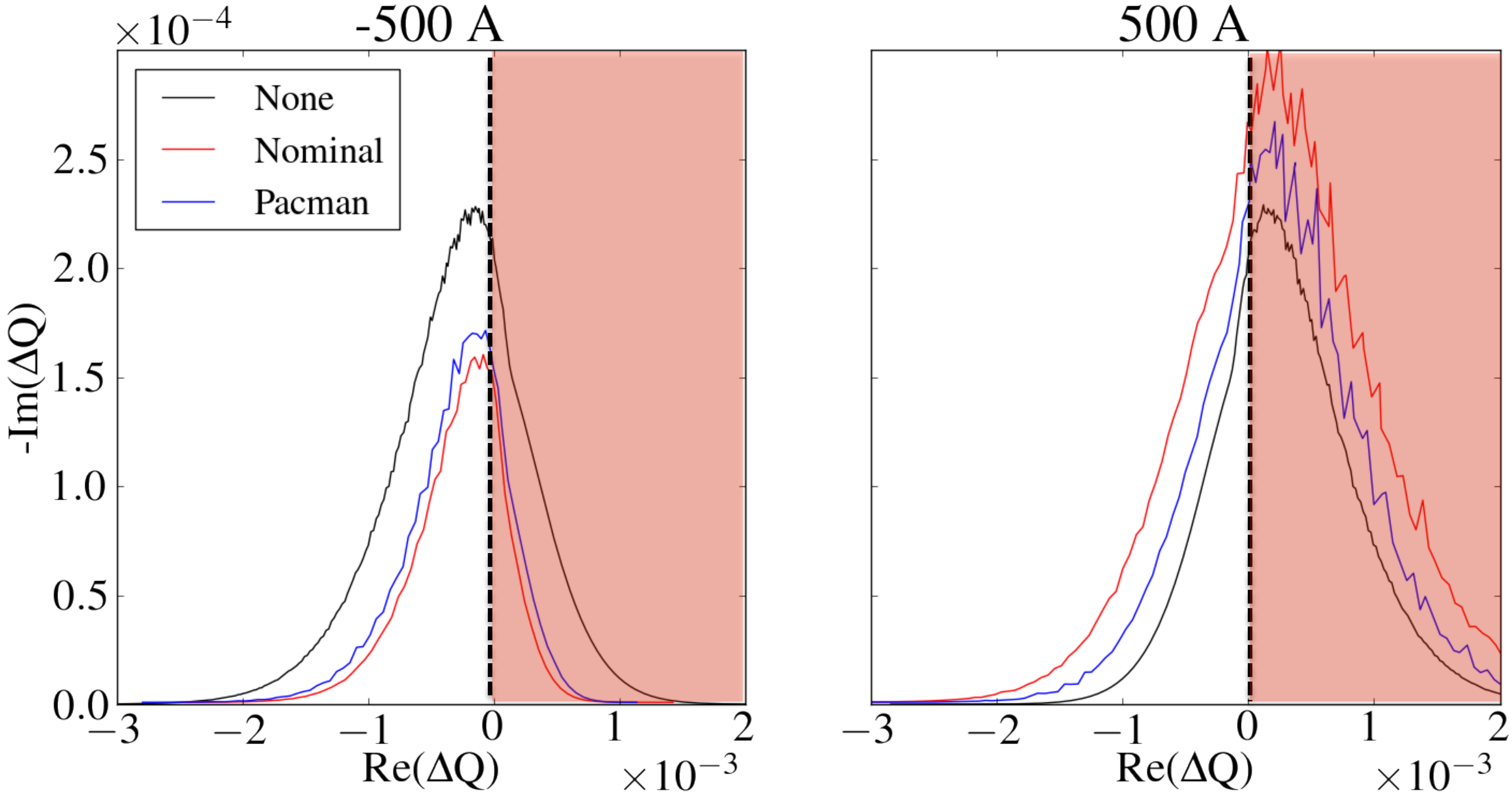
- **Positive Landau Oct Polarity**
- **Q' = 10/15 units**



- **Beam 1 Vertical Plane**
- **Coherent oscillations of selective bunches (BBQ, ADT)**
- **Very small Int losses (up to 3%)**
- **Selective emittance blow-up**
- **Clear pattern (tail bunches)**

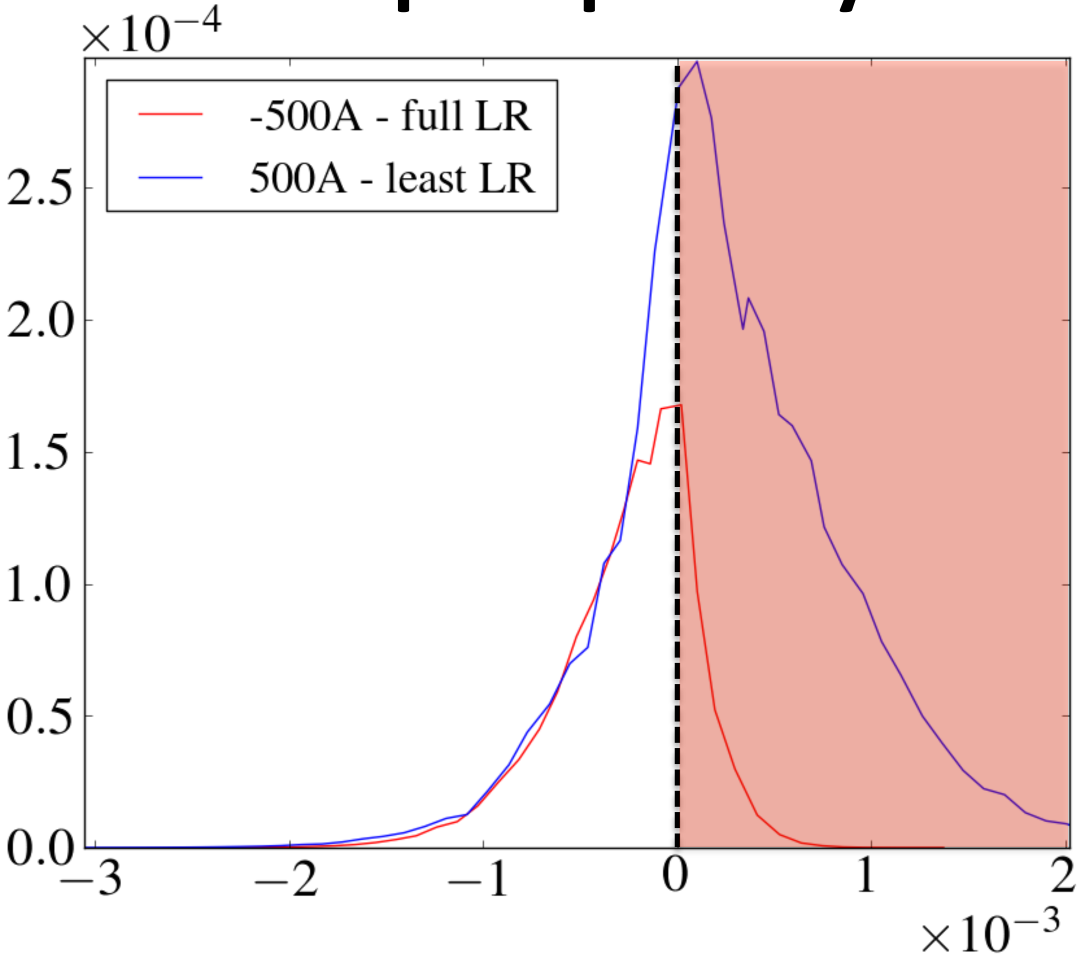
The only effective cure we are confident with: Head-on Collisions!

Long Range Beam-beam contribution to stability diagrams in the squeeze



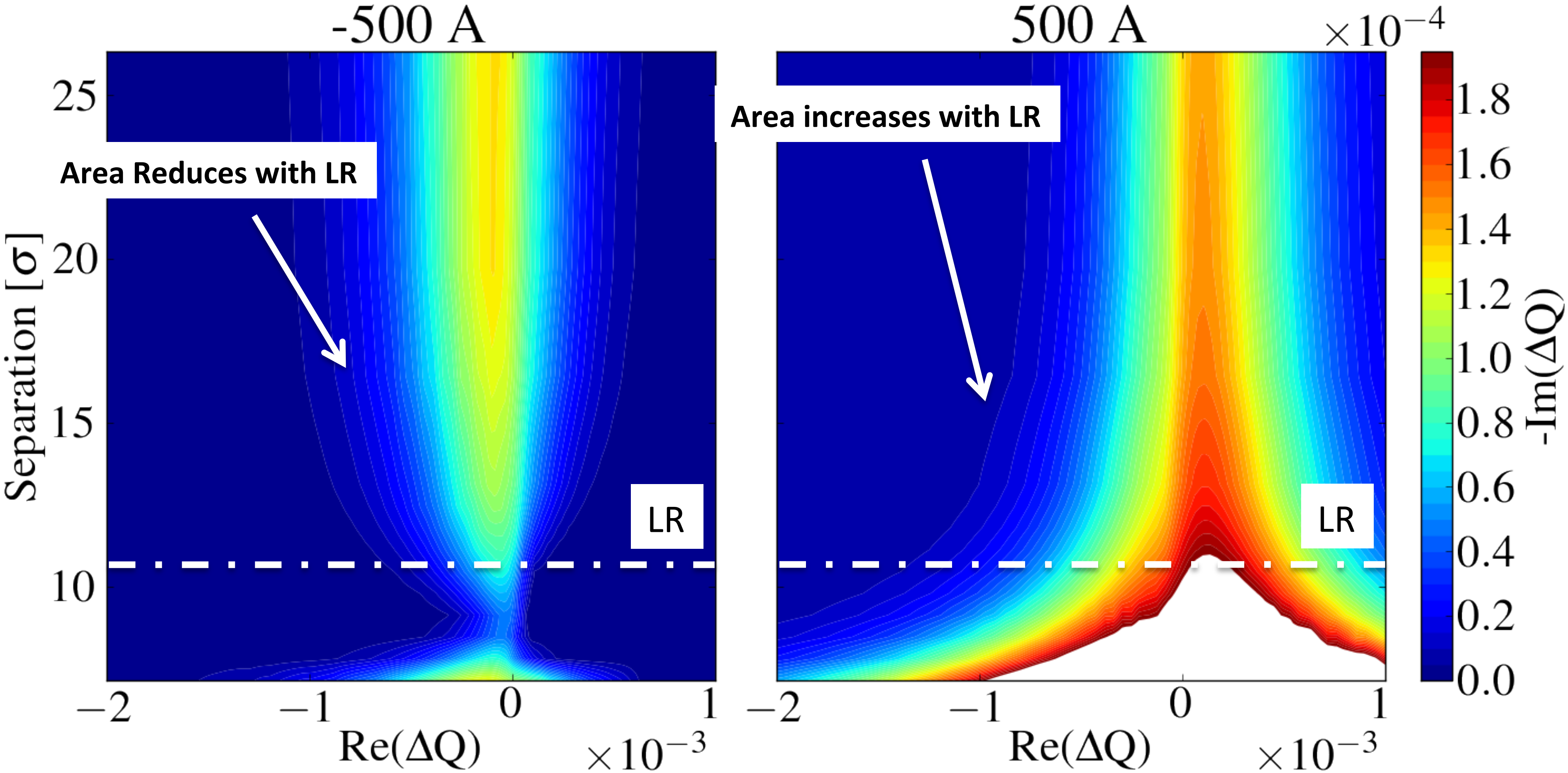
- **Long Range Beam-beam can reduce/enlarge the stability diagram depending on Landau Octupole polarity**
- **Long Ranges should be considered nominal and PACMAN bunches**

End of squeeze Stability diagrams: change of octupole polarity



Change of polarity just moved smaller stability diagram from nominal to PACMAN bunches in a train.
Partially confirmed with data!

Stability diagrams 2015 during squeeze

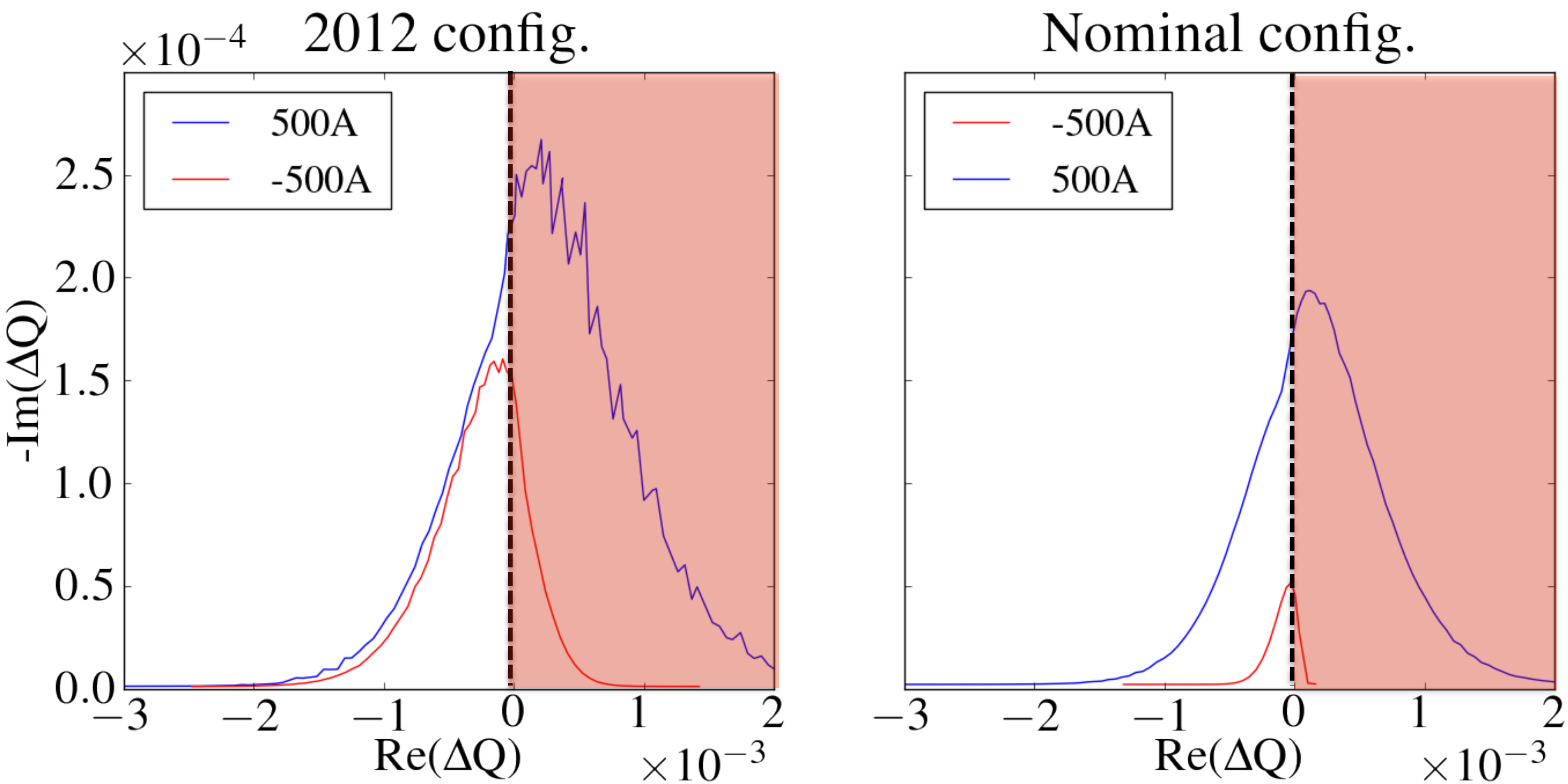


Long Range beam-beam stronger and Landau Octupoles weaker

Clear preference for positive polarity in 2015

(for maximum stability diagram)

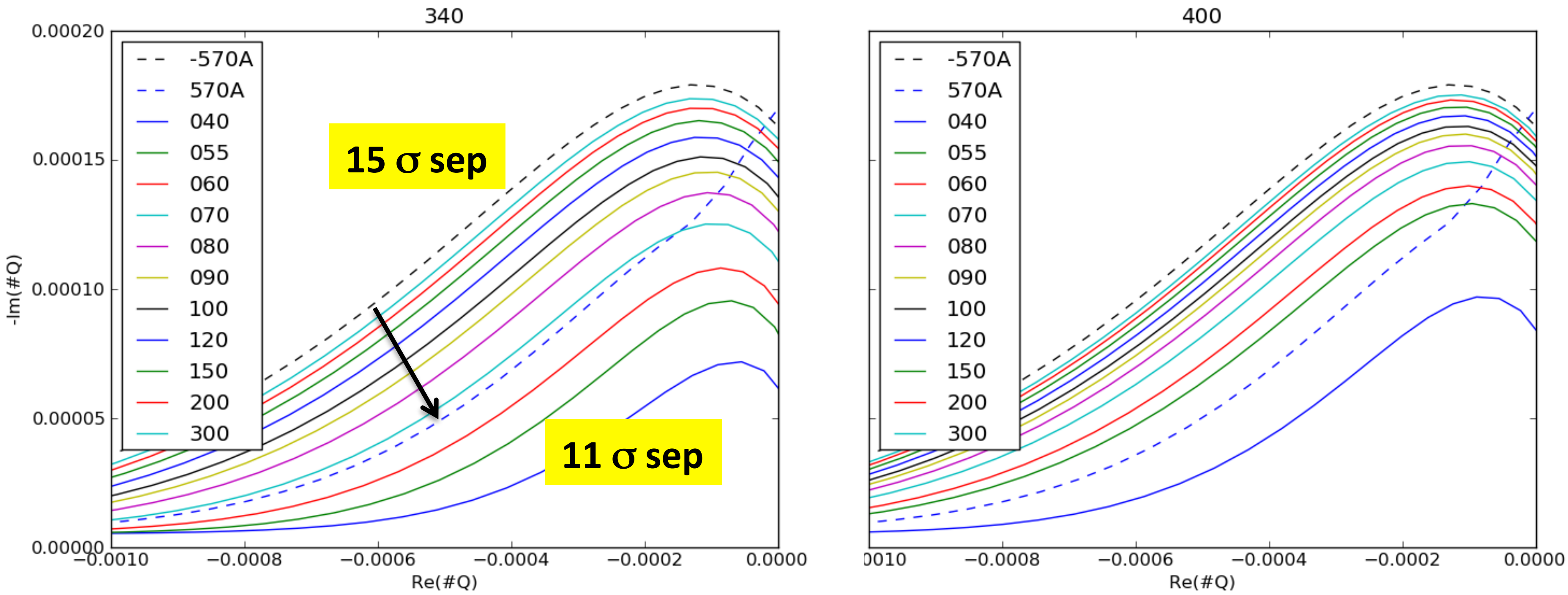
2012 versus 2015
Long Range effect & Landau Octupole



In 2015 there is a clear preference for positive!

Can we reduce in the squeeze the LR effects with LOF negative?

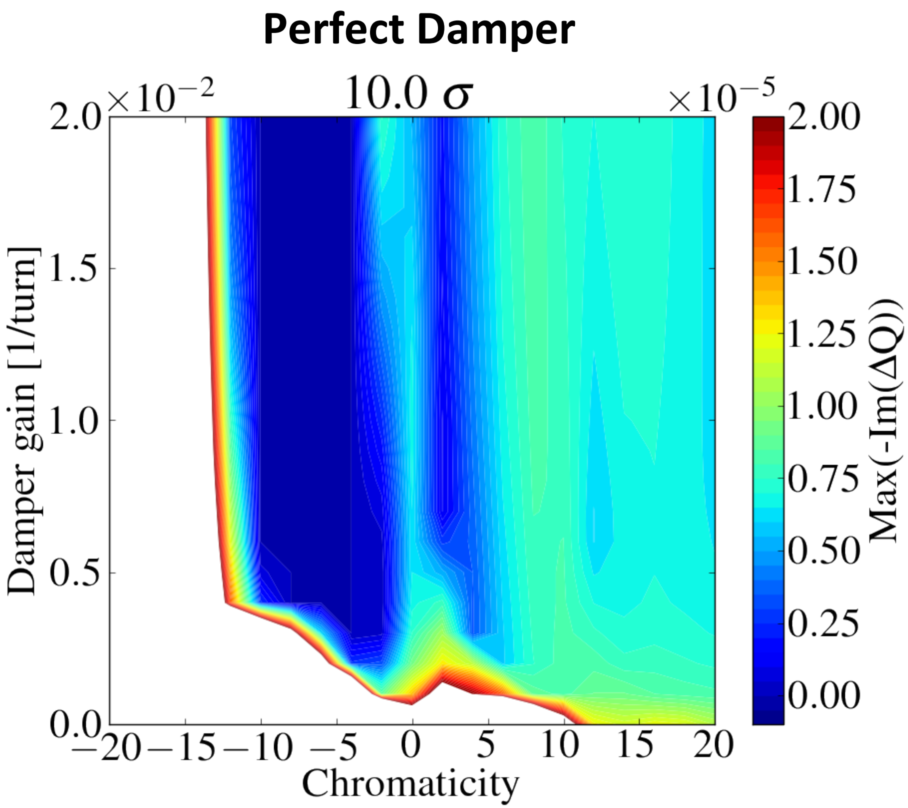
Question raised by S. Fartoukh

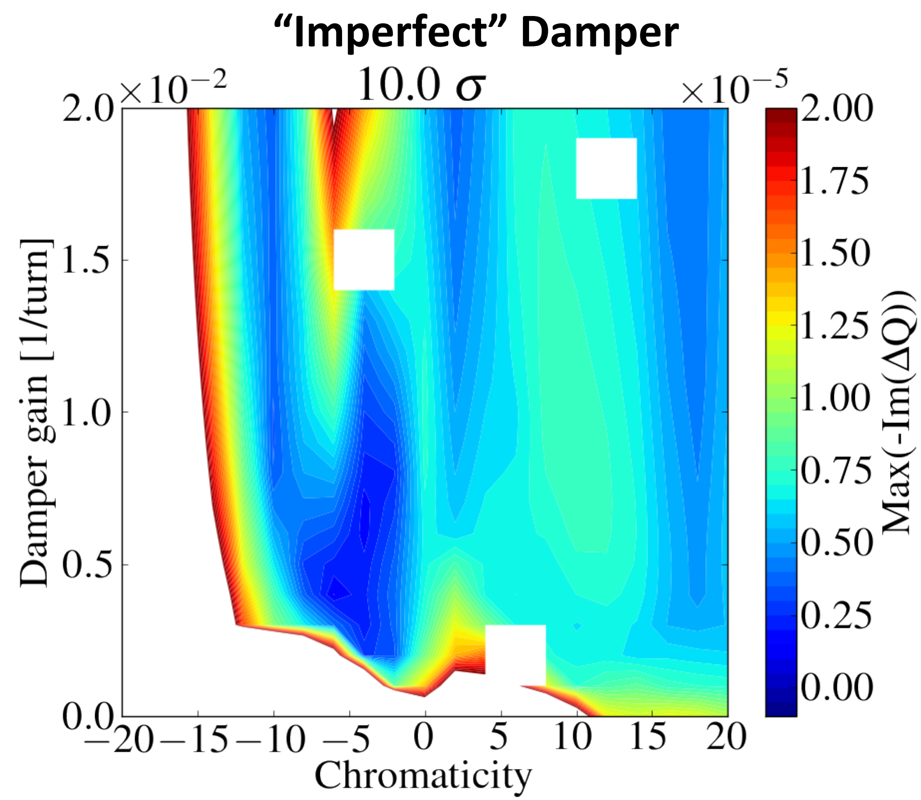


Yes we can!

Opens possibility to go for negative polarity without collide&squeeze!

Did we forget anything?





Beam-beam is not only contributing to stability diagrams!

Transverse feedback has an important role in stability of two beams

(coherent BB & impedance, particle distributions)

Chromaticity scan confirms a smoother area at **higher values**, "plateau"!

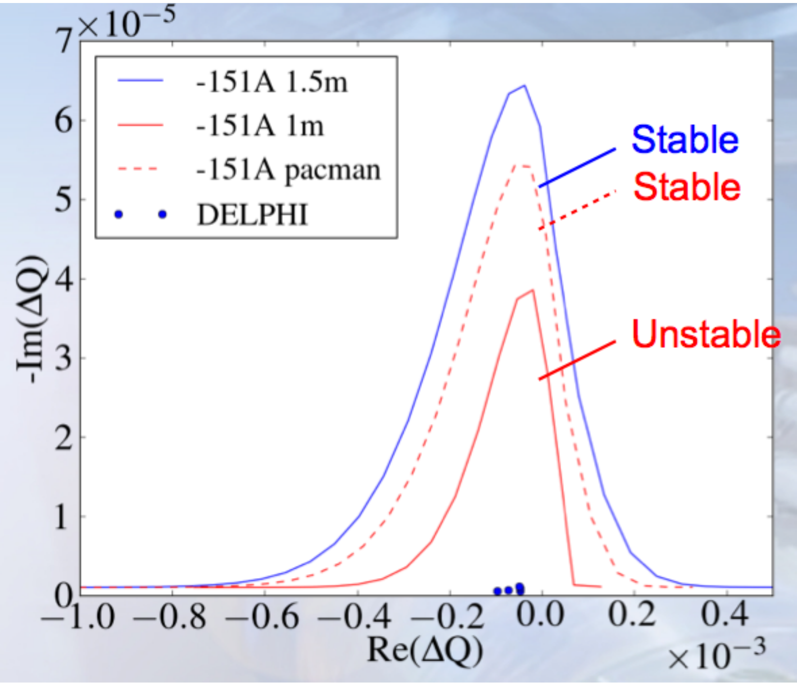
On-going studies with ADT Team.

EoS instabilities 2012

- **End of Squeeze Instability was never cured!**
- **The stability diagram reduction cannot explain the instabilities observed 2012!**
- **Strategy guarantee the largest Landau Damping area**
- **We need to observe the limits and understand the missing ingredients (ADT)!**
- **Need step by step validation of our models during start-up phase!**

The only effective cure is Landau damping from core particles: head-on collision

Exemple on 2011 case



Collide&Squeeze: we are confident it is the most robust cure, in case of problems!

We need to make sure it is a OP robust solution!

Adjust

Question raised by G. Arduini

- Present only first part year
- In adjust sep in X-ing still resent after collapse in sep plane
- Instabilities during adjust where of same nature as EOS
- No instabilities going through the minimum due to head-on, 1.5 σ sep

Collapse X-ing sep early, to be avoided in 2015!
None (2) adjust instabilities, only EOS…!

IP8 snowflakes

- Present the whole year (18vs37)
- Lack Landau Damping due to missing HO
- Minimum of stability at 1.5 σ, confirmed by fills analysis
- Minimum in Vertical plane as instability always V plane
- Single beam oscillations, no sign of coherent BB

They were present also in 2nd part year. Relates well to minimum of stability of Head-on if private bunches in then we expect!

Proposed strategy negative LOF best for single beam and most performing Lumi:

(A) **Test Collide and Squeeze**

Only solution in case of problems!

Pros: we have it in our pockets!
Cons: If it doesn't work we need to know and change our strategy.

Proposed strategy negative LOF:

(A) **Test Collide and Squeeze**

(B) **50 ns: LOF negative & high chromaticity**

(important milestone for models)

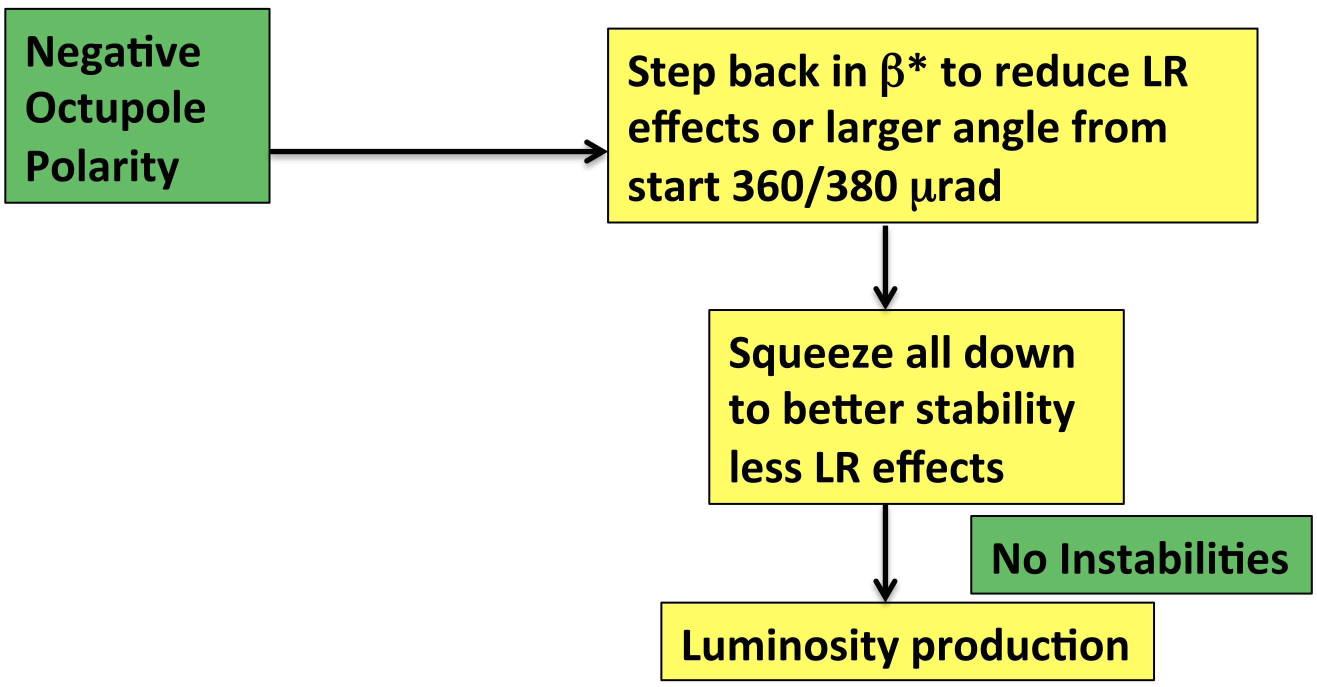
Back to 2012 with negative polarity but high chromaticity (an important missing information)

Proposed strategy negative LOF:

(A) **Test Collide and Squeeze**

(B) **50 ns: LOF negative & high chromaticity**

(C) **25 ns : LOF negative & high Chromaticity**



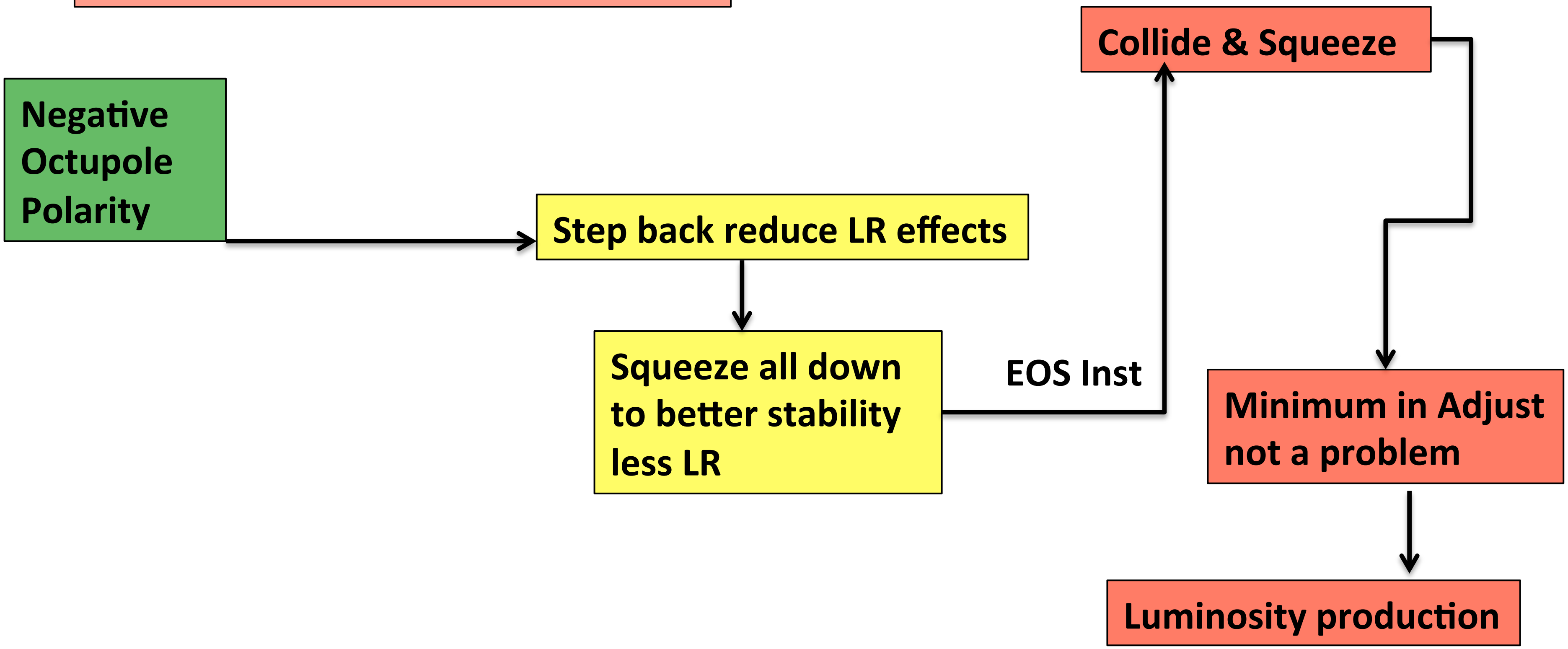
Proposed strategy negative LOF:

(A) Test Collide and Squeeze

Only solution in case of problems!

(B) 50 ns: 2012 Neg Pol 50ns high chroma

(C) 25 ns : High Chroma at start



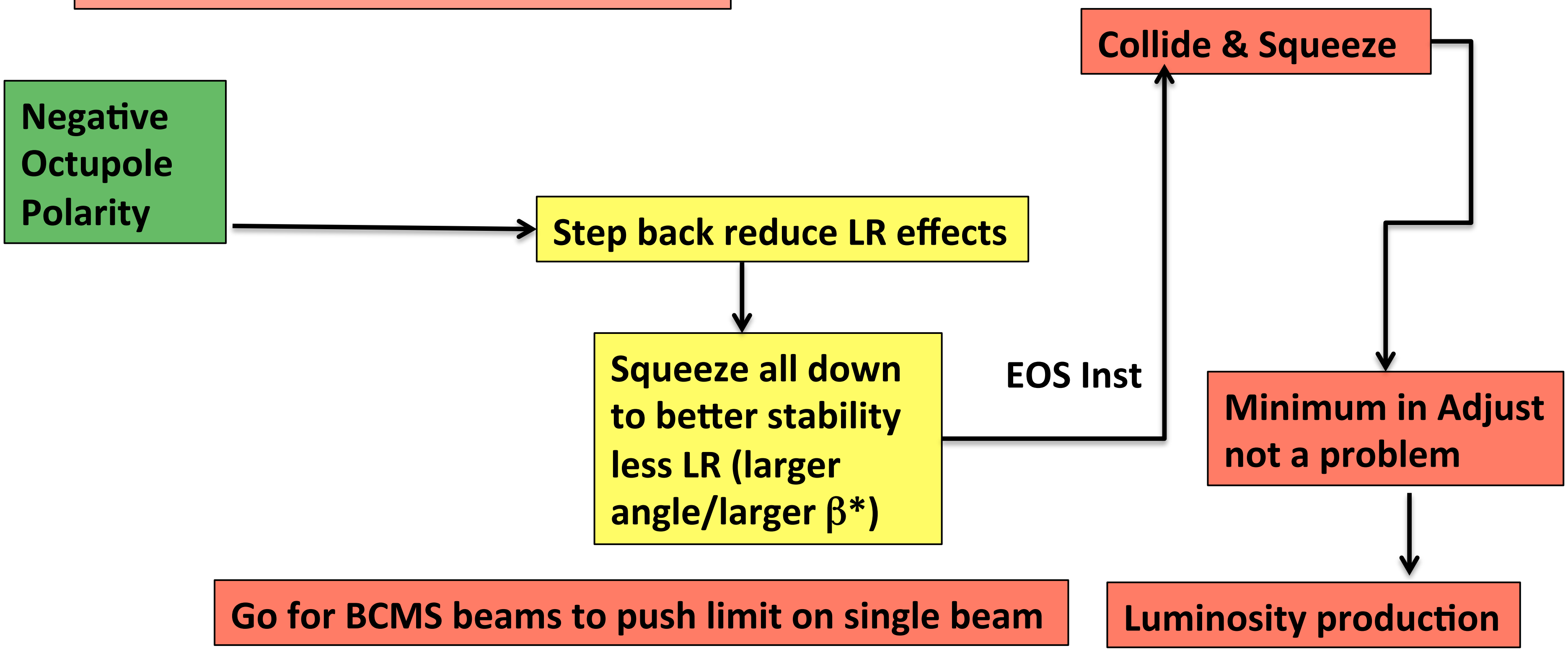
Proposed strategy negative polarity

(A) Test Collide and Squeeze

Only solution in case of problems!

(B) 50 ns: 2012 Neg Pol 50ns high chroma

(C) 25 ns : High Chroma at start



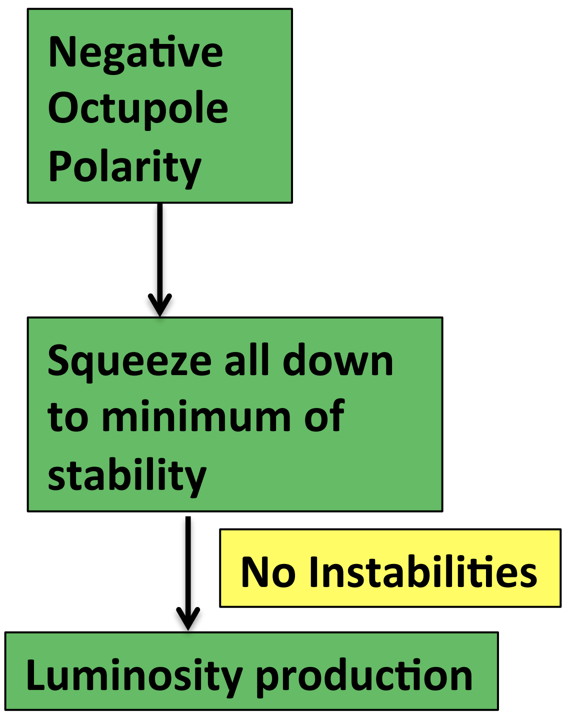
Thank You!

Proposed strategy LOF positive: single beam limit reduced brightness

(A) Test Collide and Squeeze

(B) 50 ns: LOF positive & high chromaticity

(C) 25 ns : LOF positive & high Chromaticity



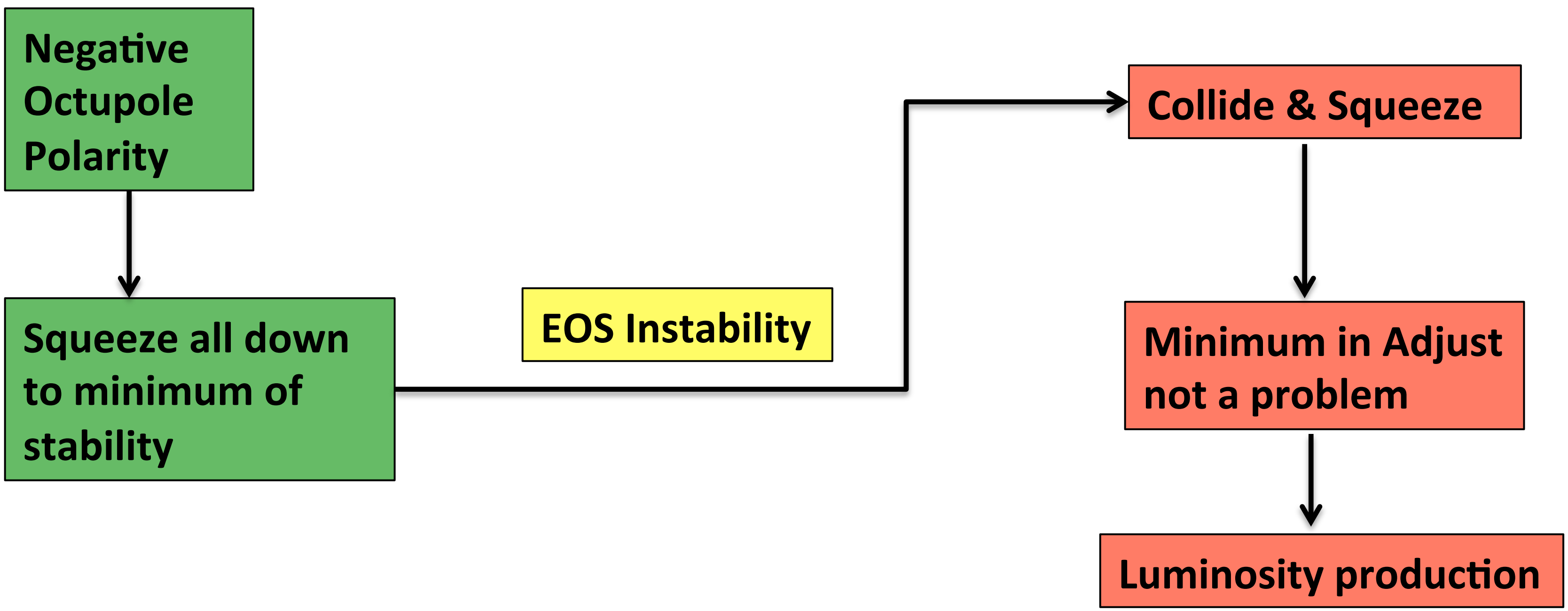
Proposed strategy LOF positive: single beam limit reduced brightness

(A) Test Collide and Squeeze

Only solution in case of problems!

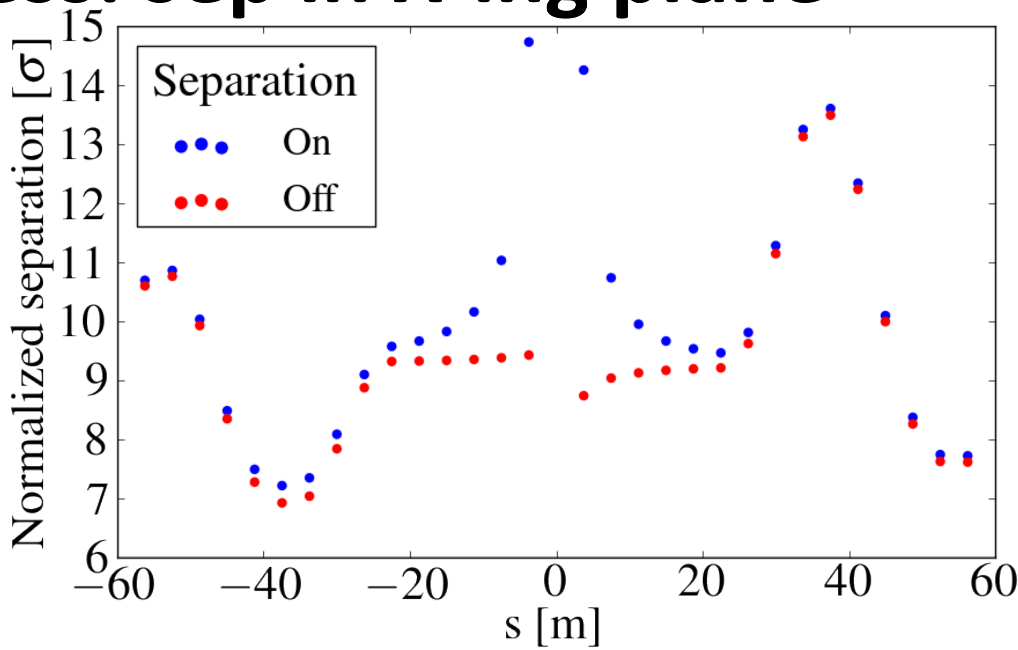
(B) 50 ns: 2012 Positive Pol 50ns high chroma

(C) 25 ns : Positive High Chroma at start



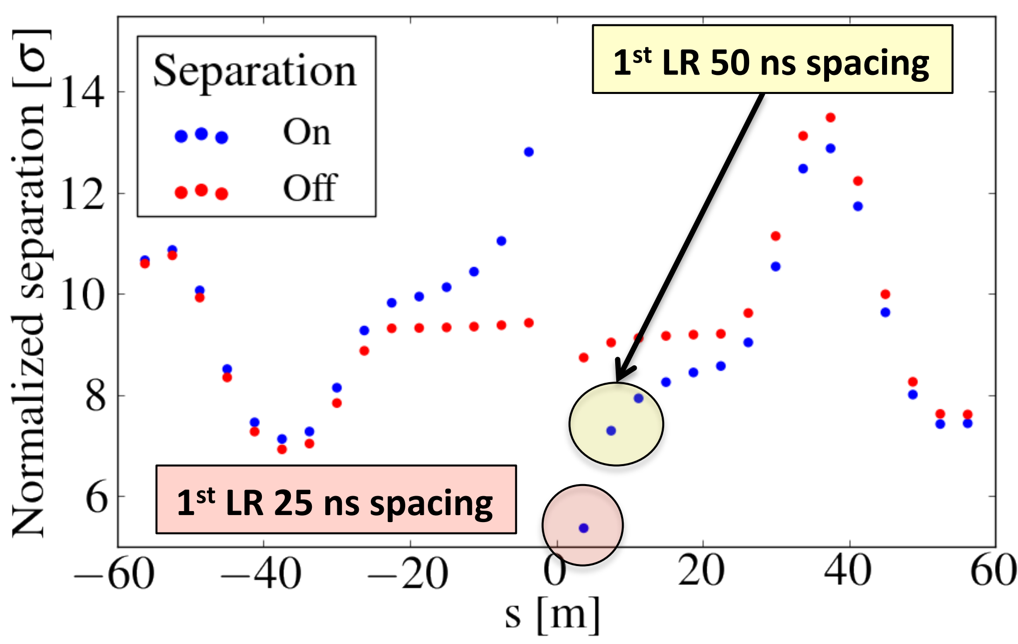
Adjust beam process: sep in X-ing plane

Sep in X-ing plane = 0 mm
Sep in Sep-plane = 0.65 mm



Sep in Crossing plane could be a problem for 25 ns should be collapsed to zero asap

Sep in X-ing plane = 0.2 mm
Sep in Sep-plane = 0.65 mm

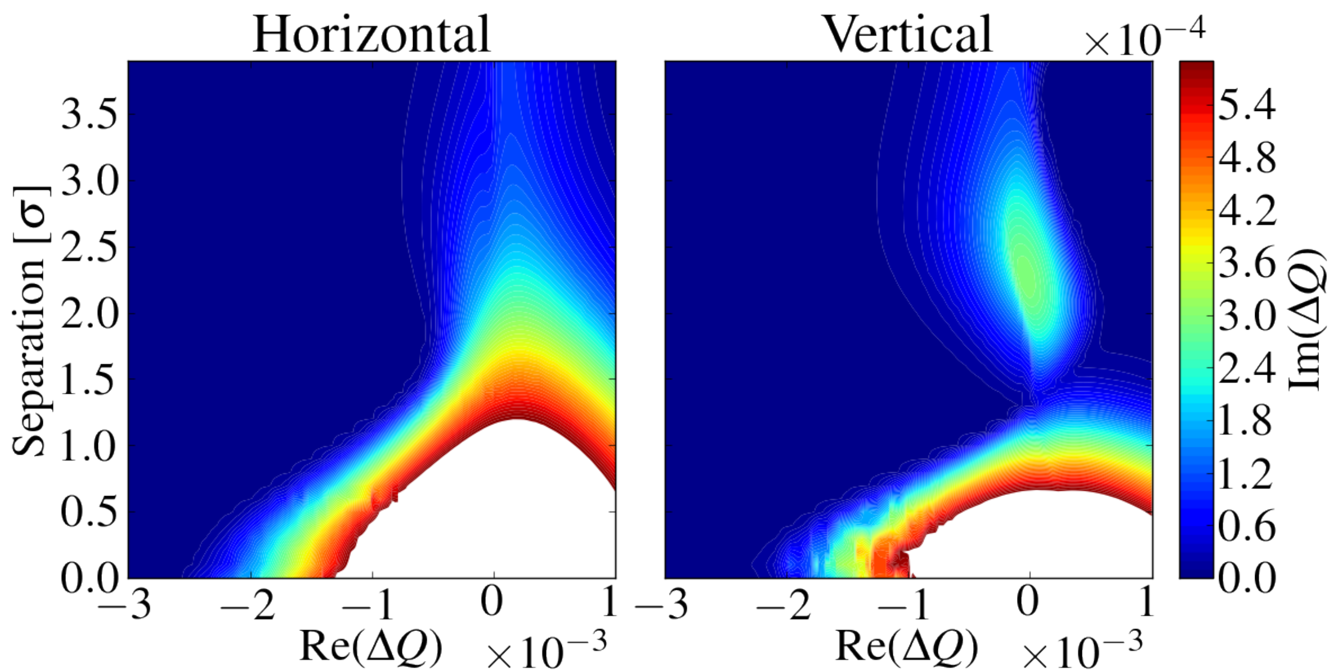


Collision beam process should be:

- **FAST**
- **Only collapse of Separation Plane**

IP 8 private bunches-Snowflake Instability

- IP8 special bunches
- Offset leveling (2.5 → 0 sep)
- Octupoles reduced (250 A)

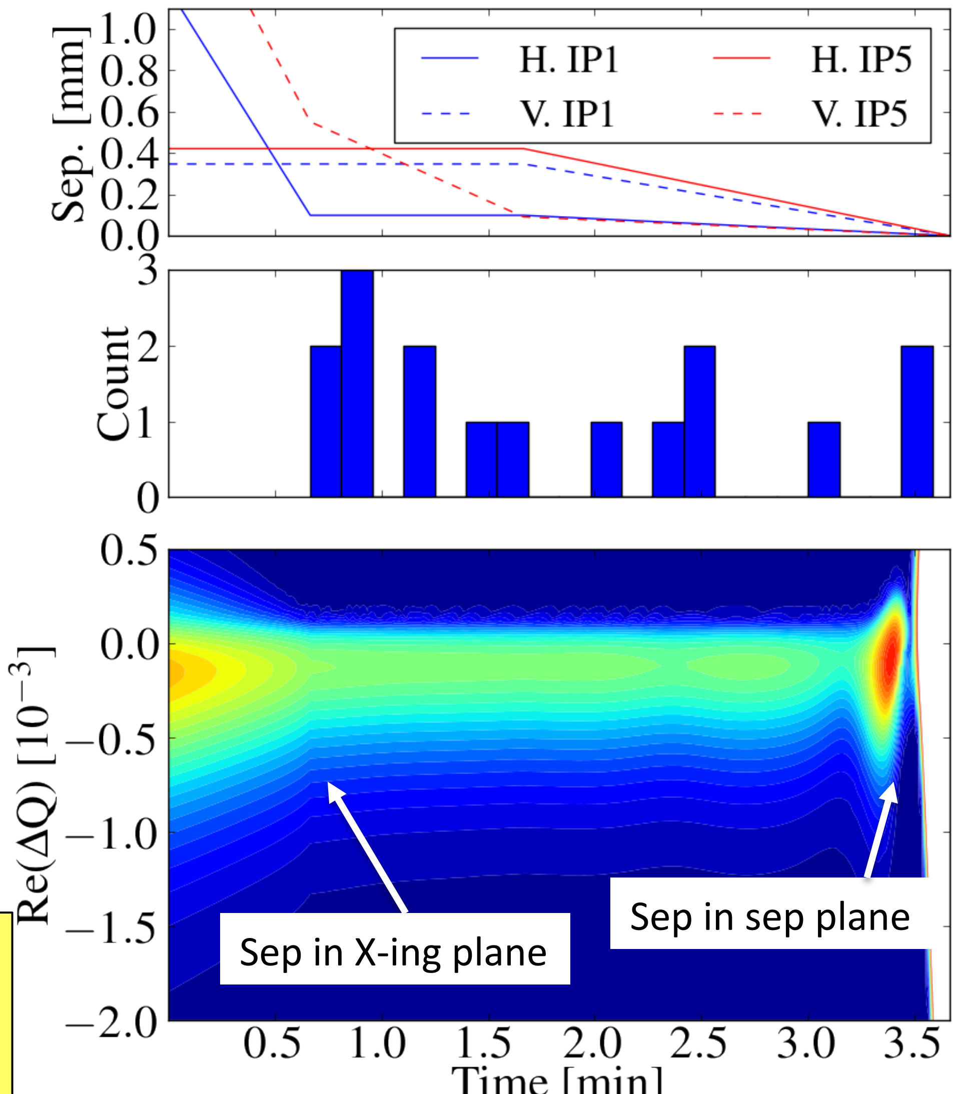


- Present the whole year (18vs37)
- Lack Landau Damping due to missing HO
- Minimum of stability at 1.5 σ, confirmed by fills analysis
- Minimum in Vertical plane as instability always V plane
- Single beam oscillations, no sign of coherent BB

Instabilities during Adjust Beam Process

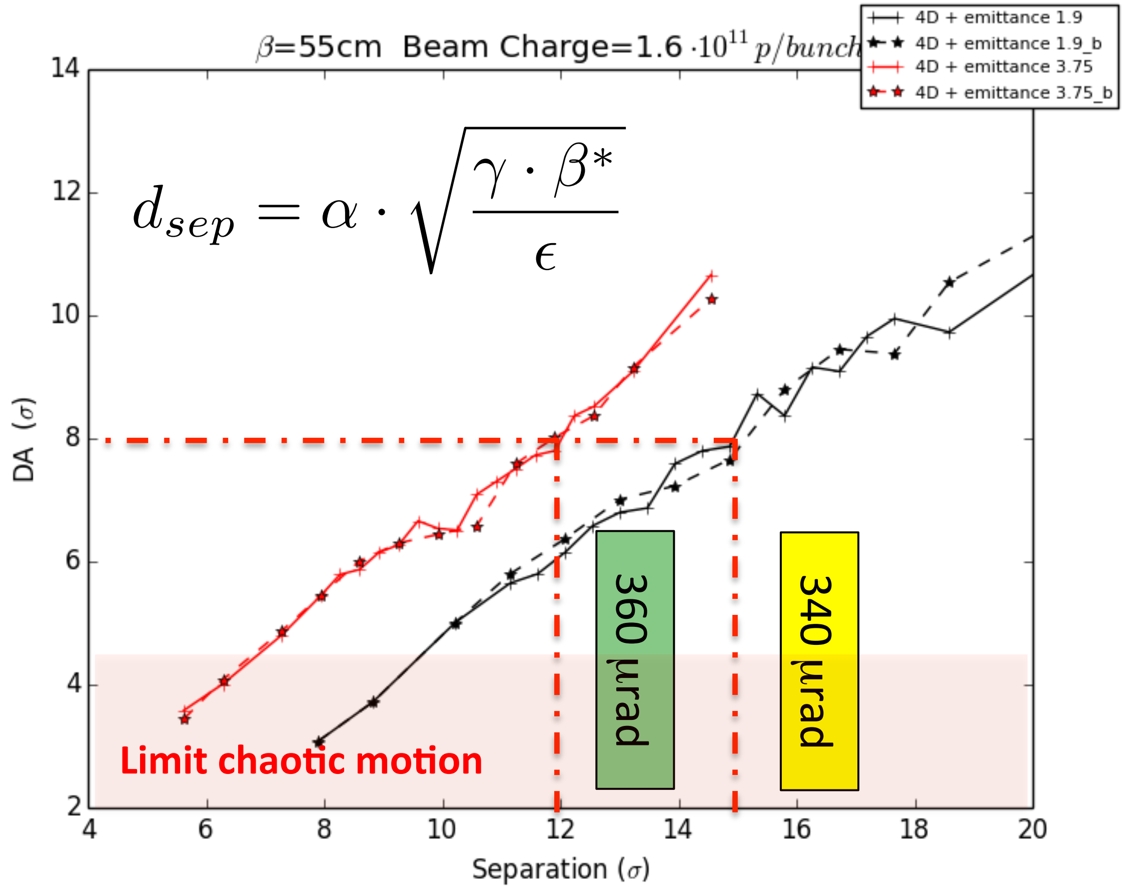
Question raised by G. Arduini

- Only 1st part Year, before MYC
- Q' = 2, collapse of sep bumps also in X-ing plane
- Collapse of X-ing bumps could give significant Q' variations
- Instabilities during adjust where of same nature as EOS
- No instabilities going through the minimum due to head-on, 1.5 σ sep



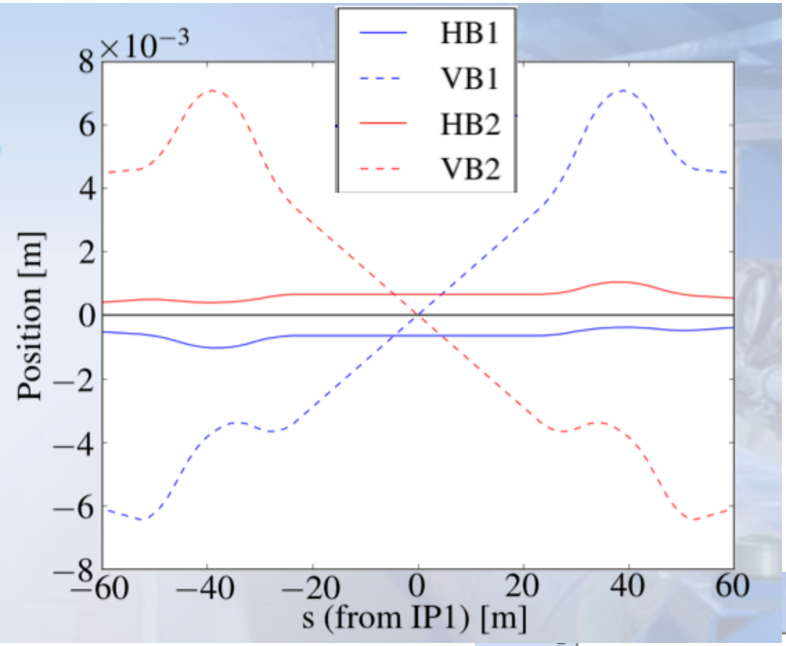
No adjust instabilities due to the minima of HO! Only EOS instabilities…

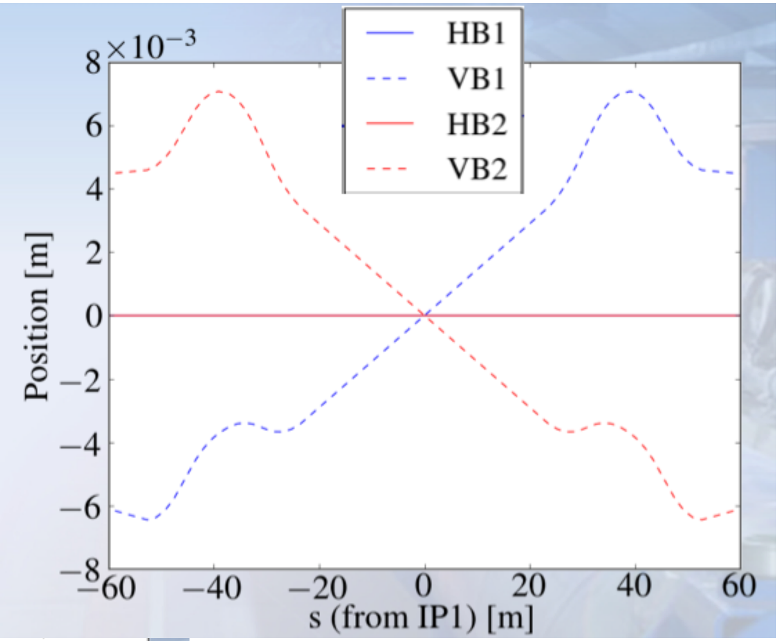
LHC 25 ns nominal and low emittance beams

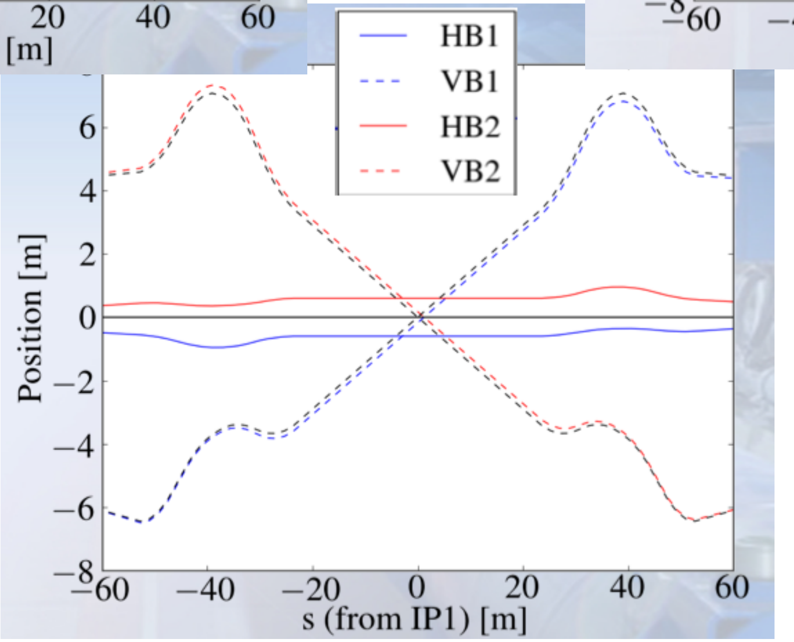


- Evaluate **the impact of IP8 leveling** on configuration (by β*, offset)
- Keep **margin for the betatron squeeze** (see later)
- Give margin for very bright beams (8b+4e beams)

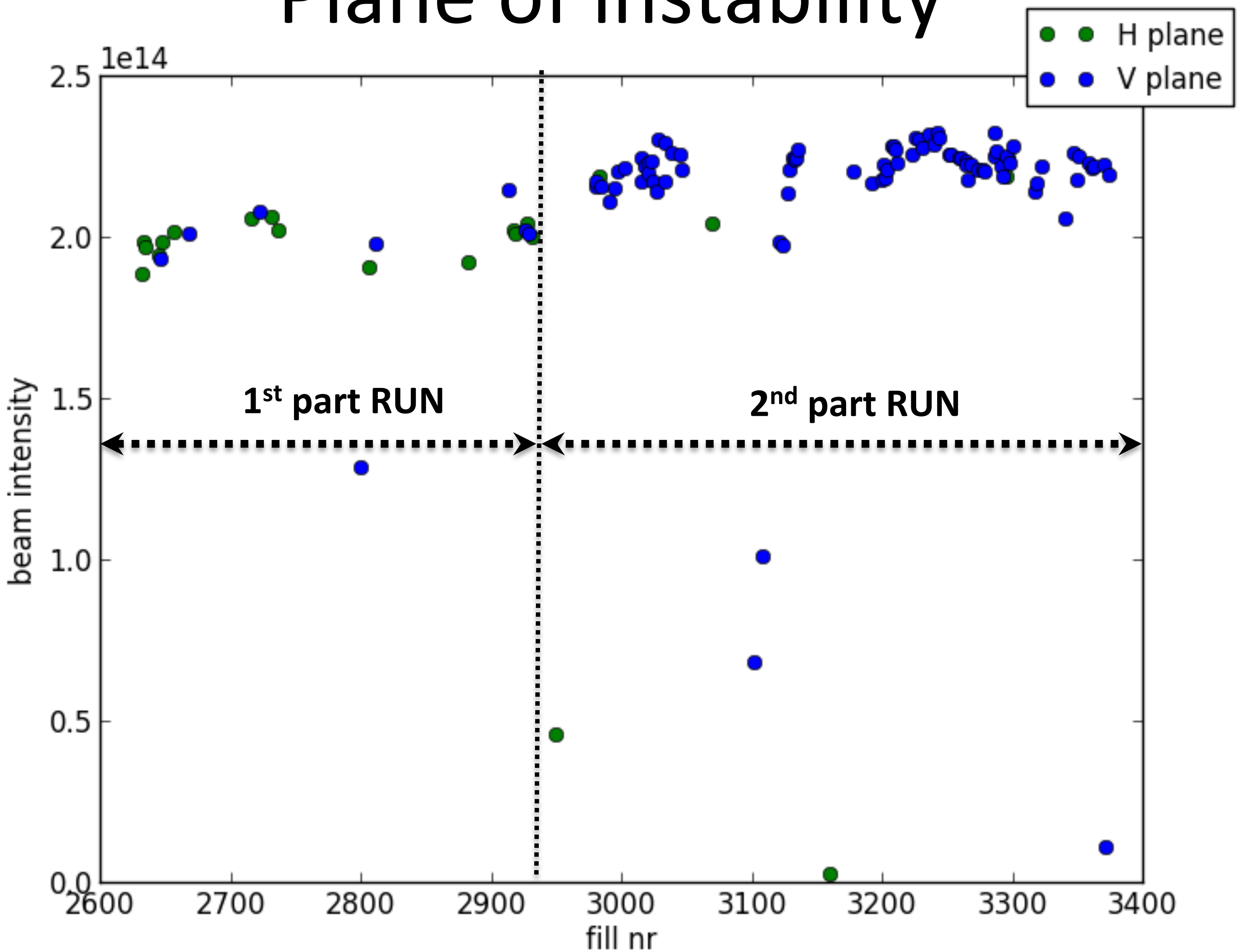
Sep in X-ing Plane







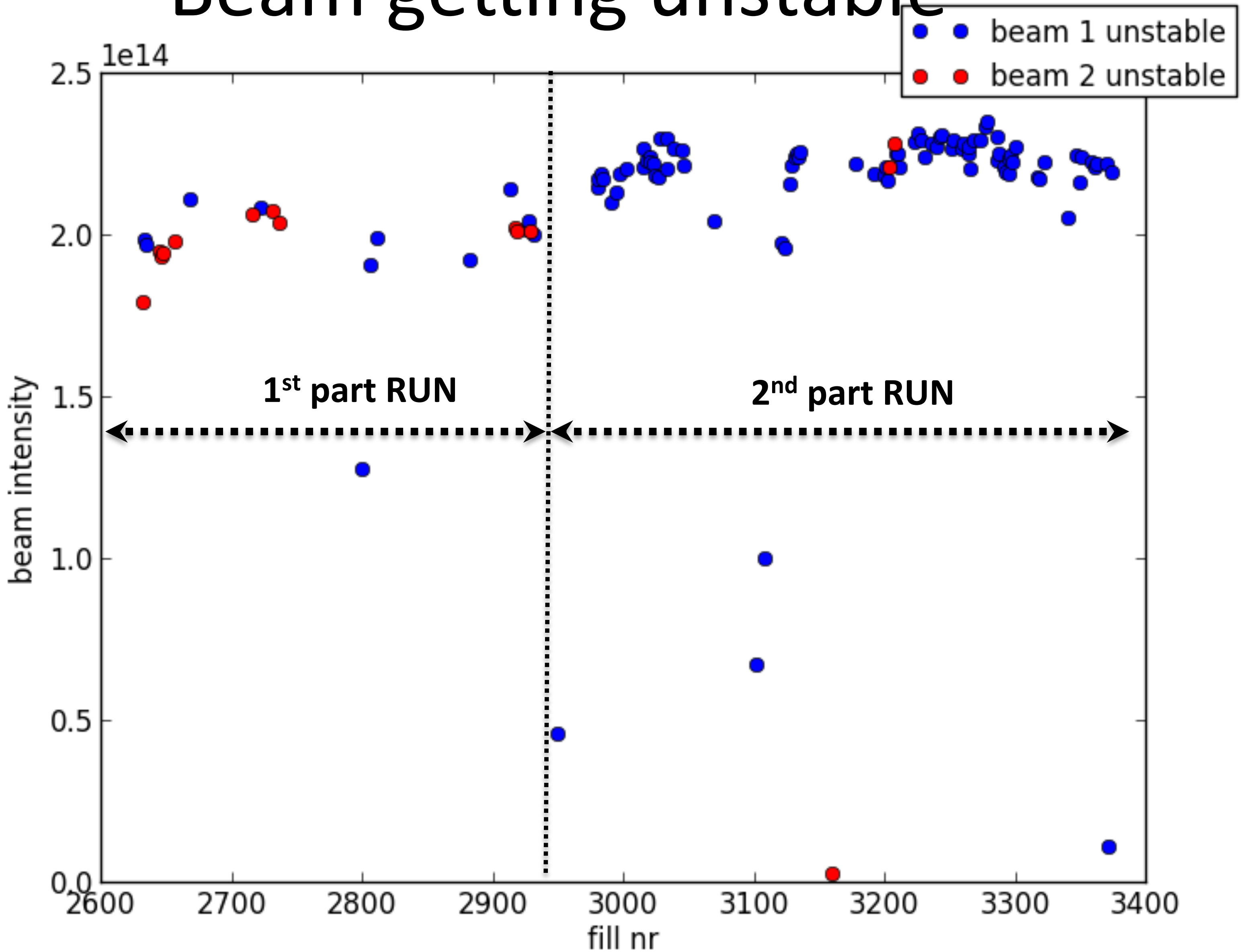
Plane of instability



1st part RUN mainly Horizontal but still some Vertical plane cases

2nd part RUN Vertical

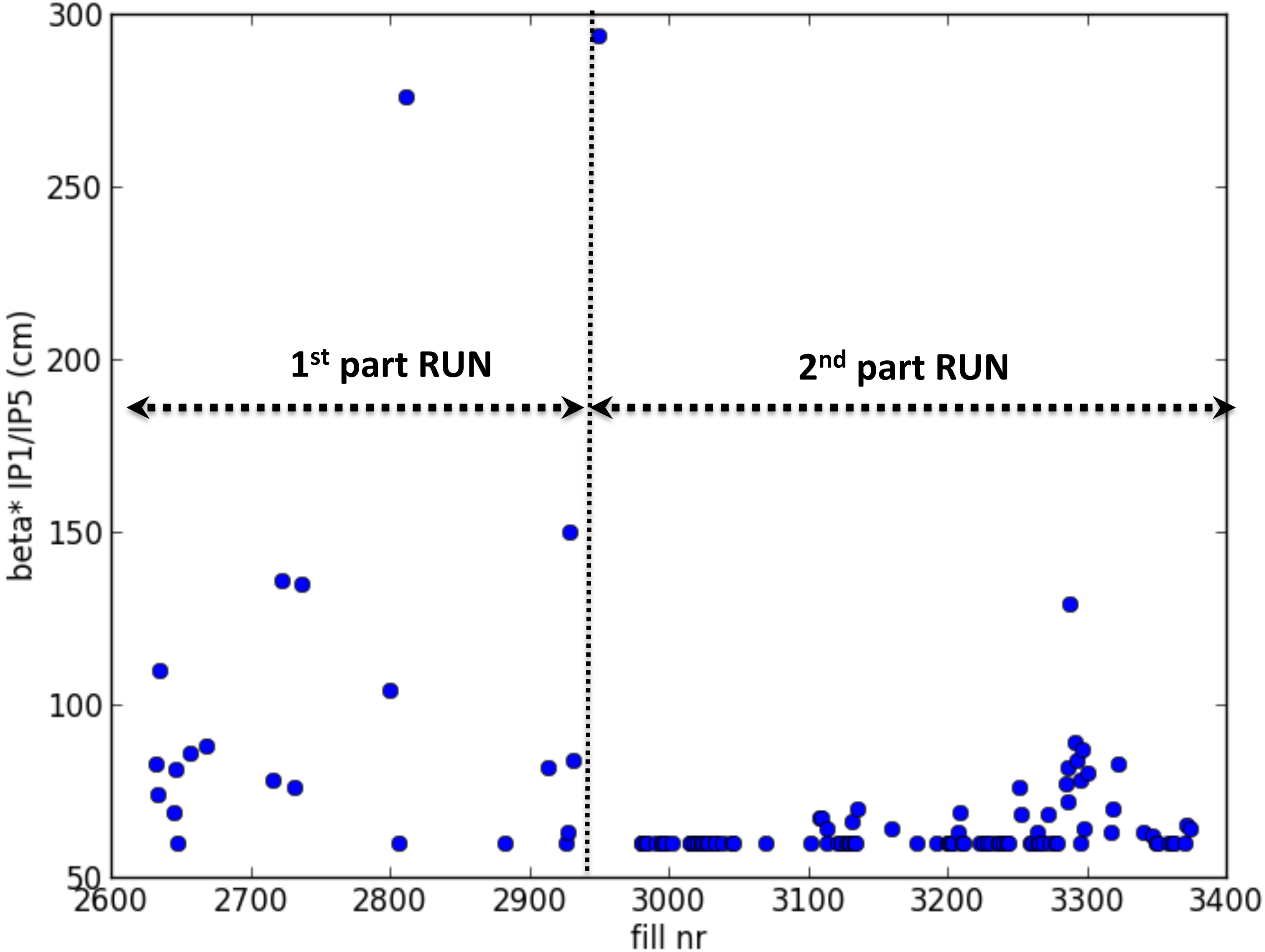
Beam getting unstable



1st part RUN both beams involved

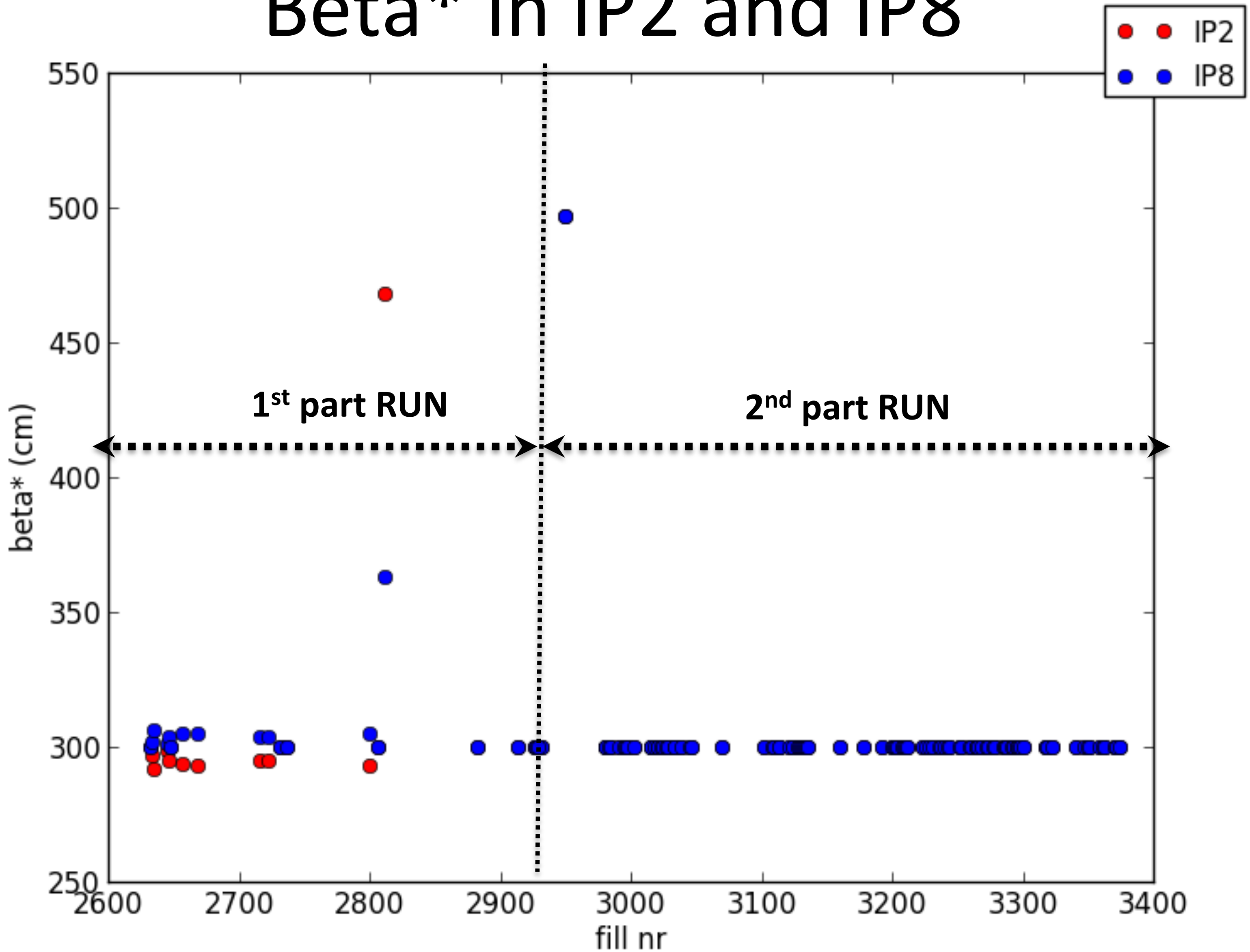
2nd part RUN mainly Beam 1

Beta* IP1 and IP5



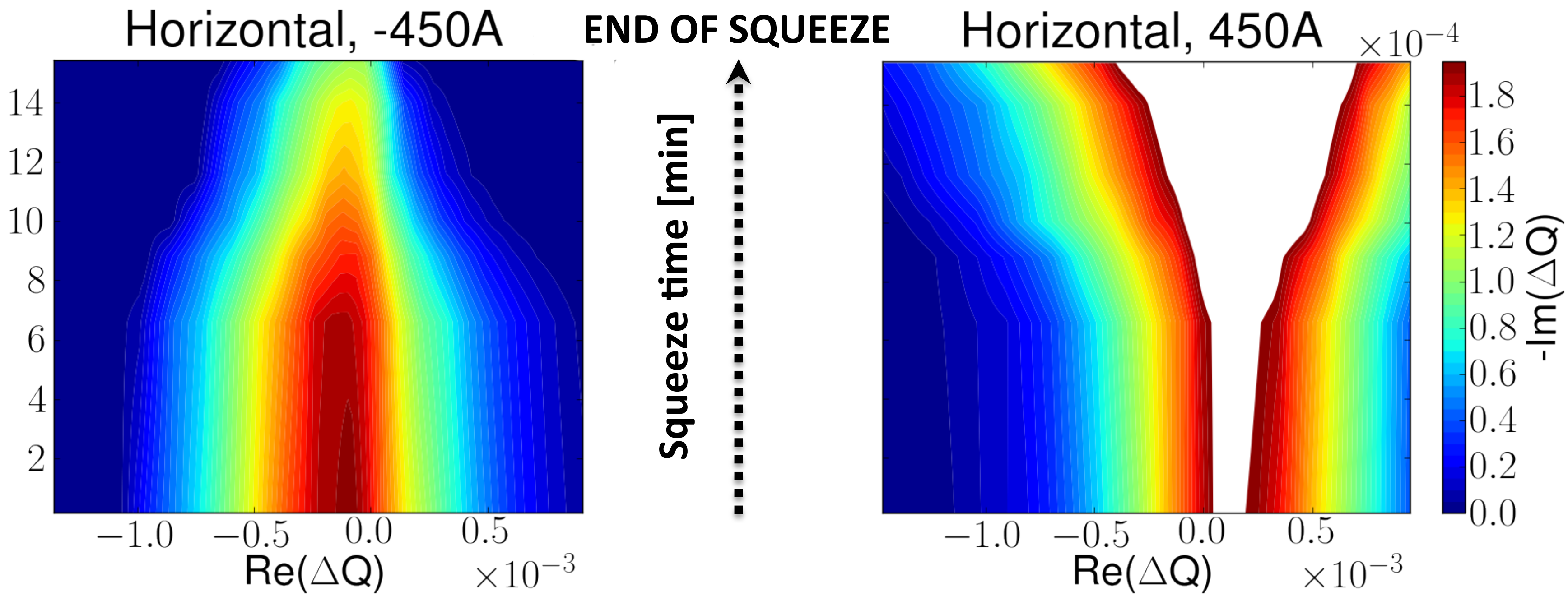
1st part RUN for beta* IP1/5 below 150 cm **2nd part RUN beta* IP1/5 below 80 cm**

Beta* in IP2 and IP8



For almost all the instabilities detected IP2 and IP8 are fully squeeze

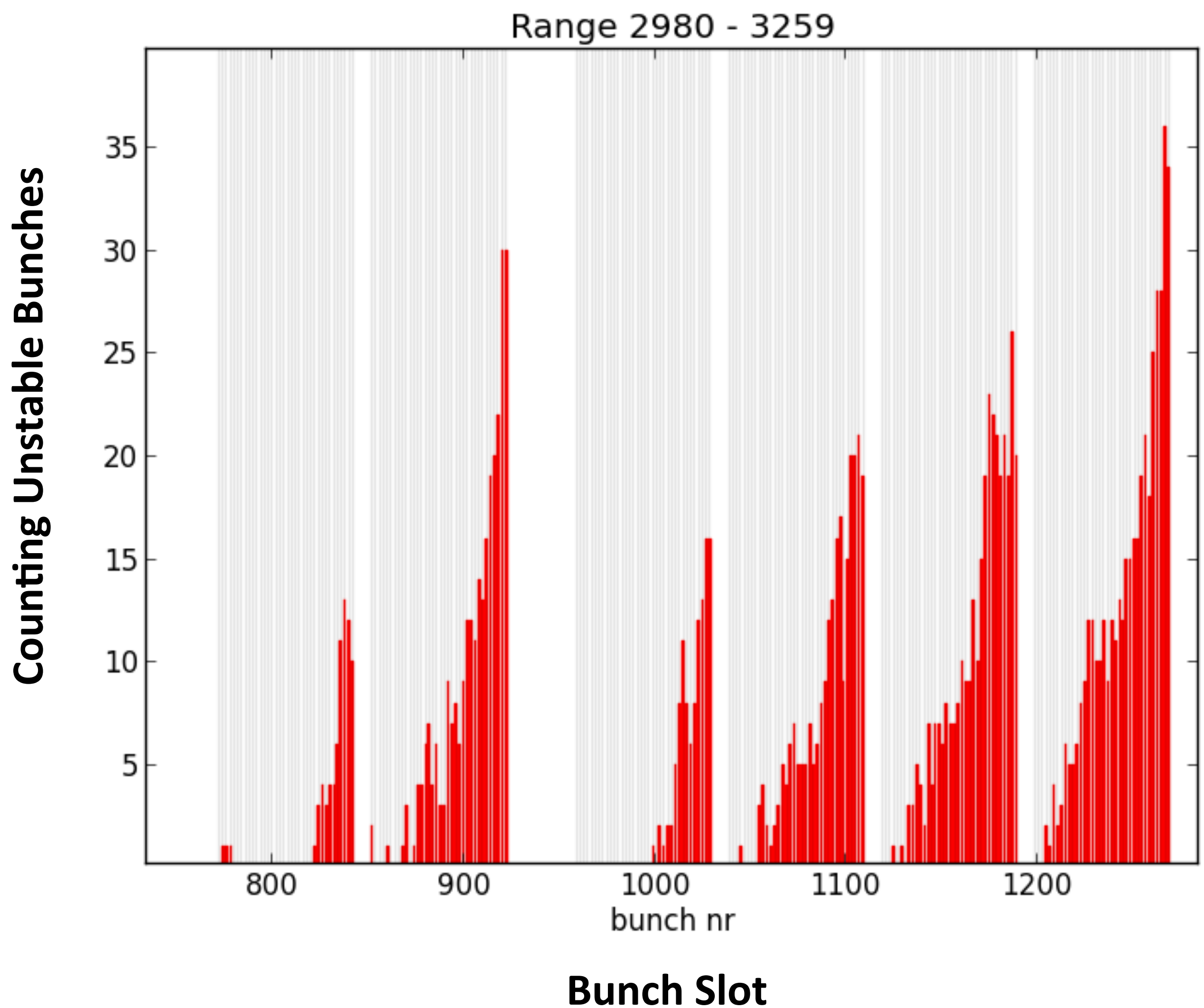
Stability diagrams during betatron squeeze



1st part RUN 2012 **2nd part RUN 2012**

Stability diagrams are better for Nominal bunches for 2nd part of Run 2012
Bbb picture can deviate from this nominal case

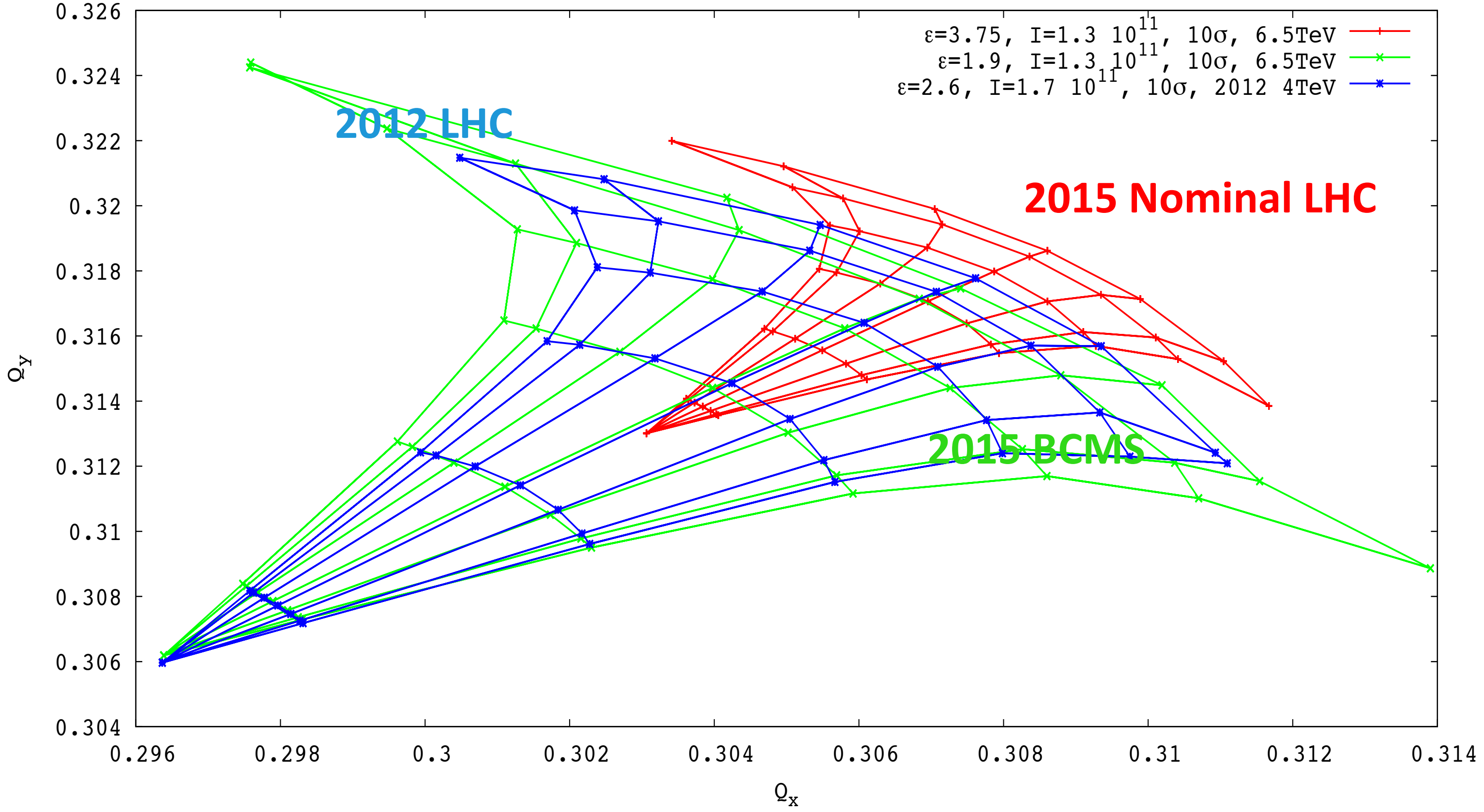
Unstable bunch pattern after MYC 2012



First Part of the year difficult to extract a clear pattern of unstable bunches!

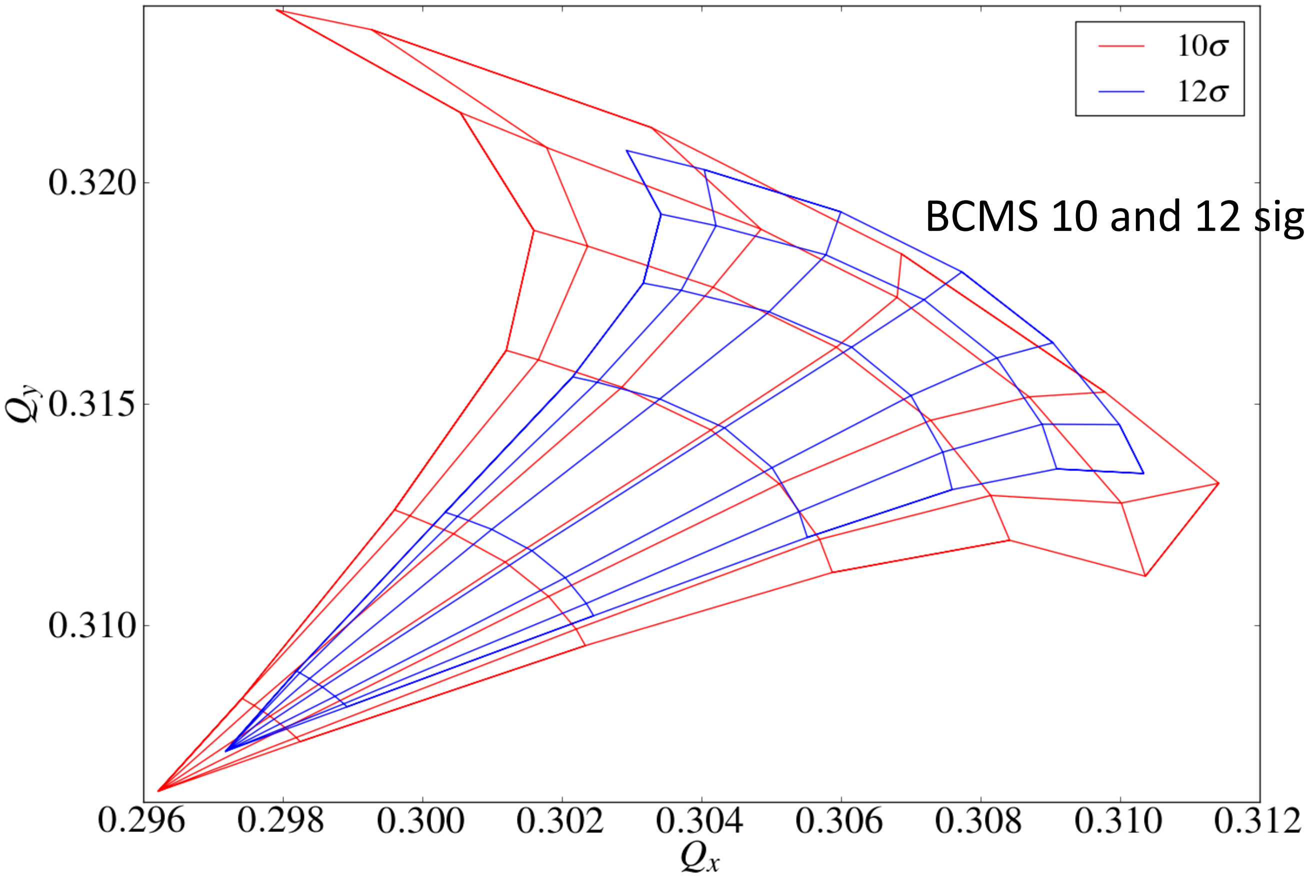
Footprints for 2012 run and 2015 Beams:

LR separation 10 σ
IP1&IP5 collision scheme
IP8 and IP2 not in offset



Long Range Separation required changes (10 to 15 σ) depending on the head-on!

25 ns LR MD 2012



BCMS 10 and 12 sigma separation

Proposed strategy:

(A) Test Collide and Squeeze

Only solution in case of problems!

(B) 50 ns: 2012 Neg Pol 50ns high chroma

(C) 25 ns : High Chroma at start