BEAM INTENSITY LIMITATIONS:

Machine settings and operational scenario from stability considerations for HL-LHC with and without harmonic system, expected intensity and stability limitations. Countermeasures (Mo-Graphite collimators, damper, octupoles)

E. Métral, G. Arduini, N. Biancacci, K. Li, N. Mounet, T. Pieloni, B. Salvant, C. Tambasco. **Thanks to HSC section, WP2 Task 2.4 and all the people working / helping on our collective effects and high-intensity issues**

(20 + 5 min talk)

- **Introduction**
- **New material needed for the collimators**
- **Crab Cavities**
- **High Harmonic RF system**
- **Beam-beam and octupoles**
- **Conclusion**

High Luminosity LHC

INTRODUCTION

- The LHC beam was already at the limit of transverse beam stability in 2012 (with ~ maximum Landau octupoles, ~ maximum transverse damper gain and ~ maximum chromaticity)

INTRODUCTION

- The LHC beam was already at the limit of transverse beam stability in 2012 (with ~ maximum Landau octupoles, ~ maximum transverse damper gain and ~ maximum chromaticity)

- Should be
  - More critical at higher energy
  - More critical for higher bunch brightness (bunch intensity / emittance)

INTRODUCTION

- The LHC beam was already at the limit of transverse beam stability in 2012 (with ~ maximum Landau octupoles, ~ maximum transverse damper gain and ~ maximum chromaticity)

- Should be
  - More critical at higher energy
  - More critical for higher bunch brightness (bunch intensity / emittance)

=> How will it be possible to reach the HL-LHC parameters?

INTRODUCTION

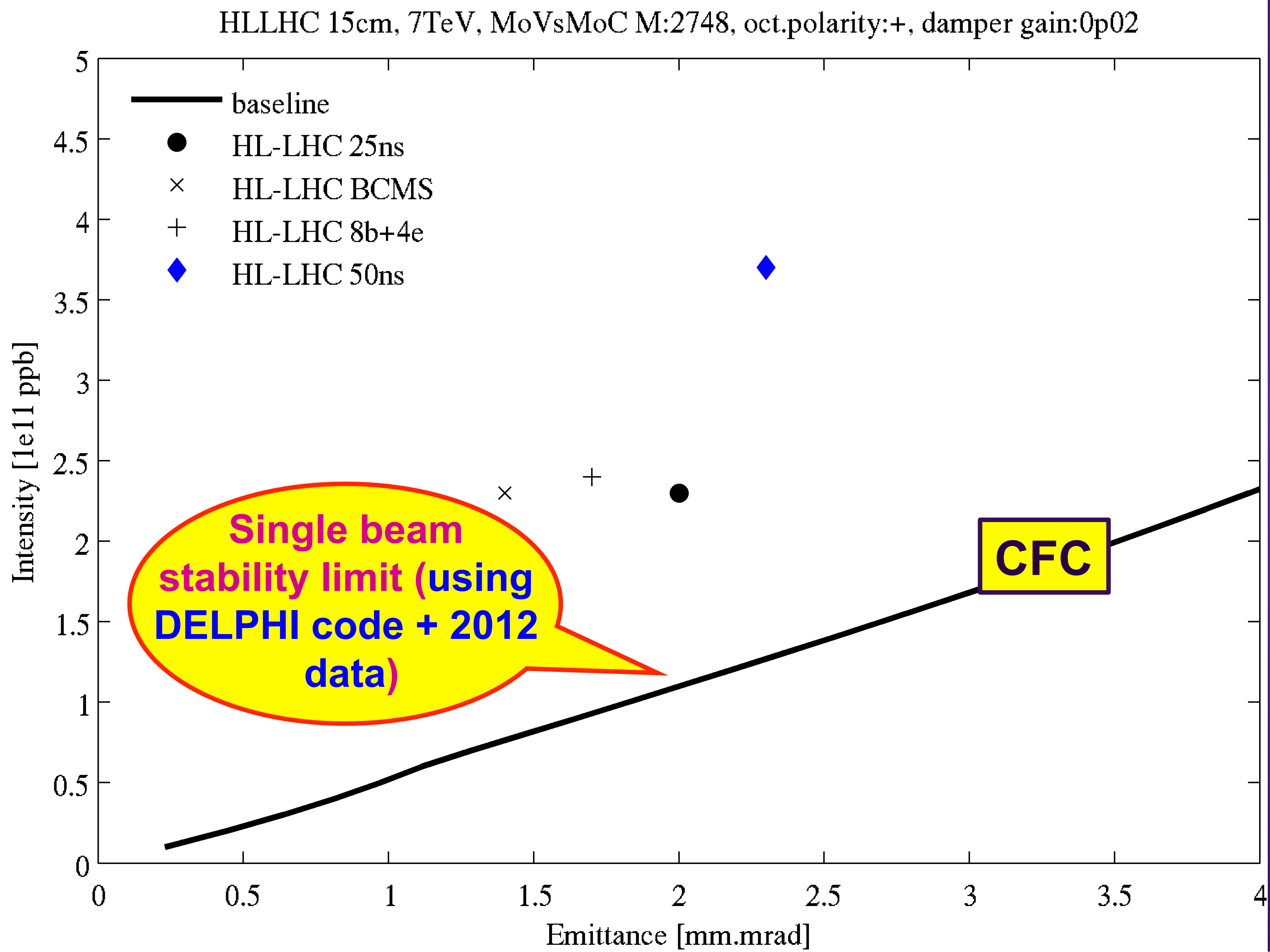
- The LHC beam was already at the limit of transverse beam stability in 2012 (with ~ maximum Landau octupoles, ~ maximum transverse damper gain and ~ maximum chromaticity)

- Should be
  - More critical at higher energy
  - More critical for higher bunch brightness (bunch intensity / emittance)

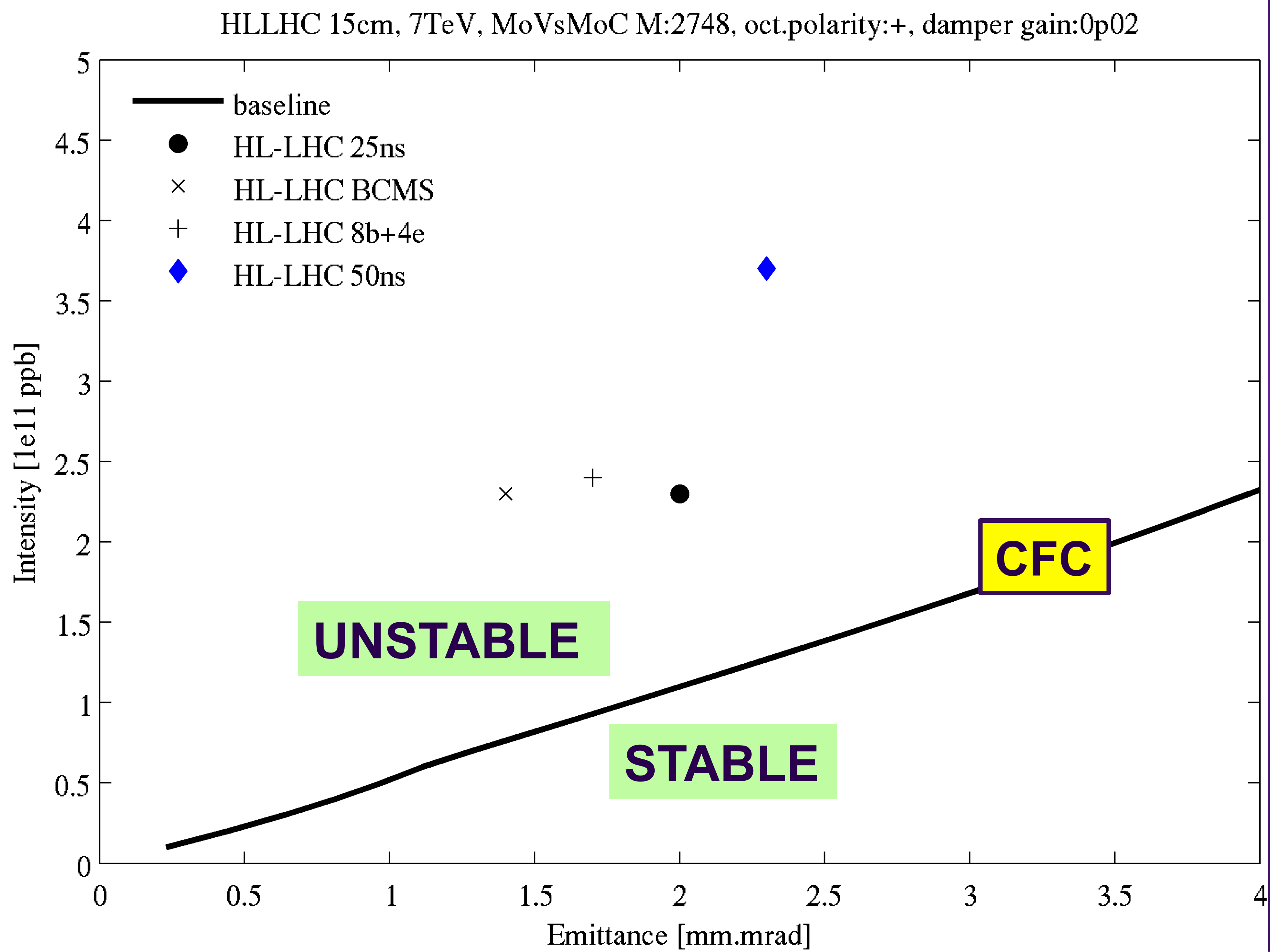
=> How will it be possible to reach the HL-LHC parameters?

- Note: Beam-induced RF heating, e-cloud effects and beam-beam effects discussed elsewhere

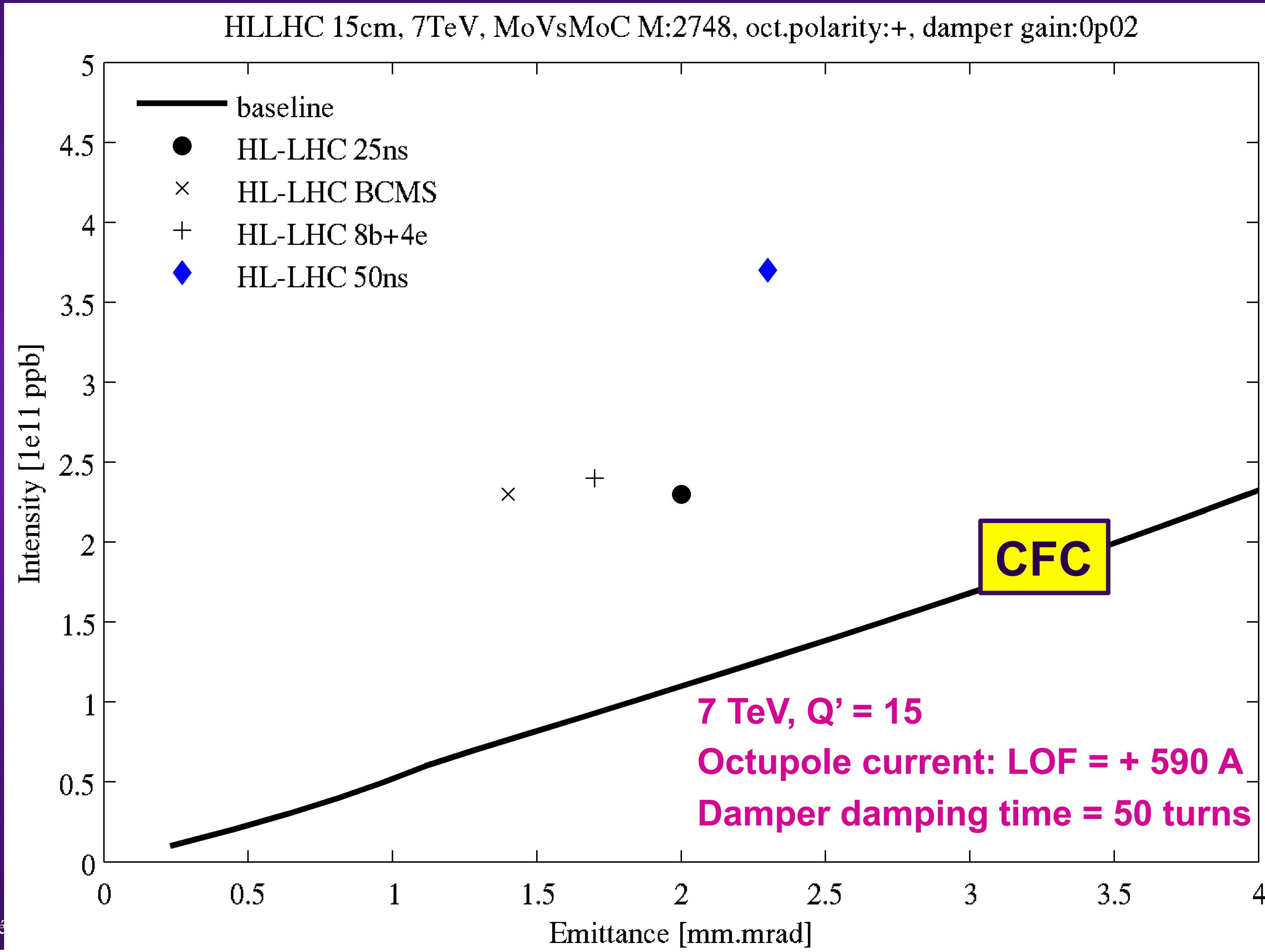
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



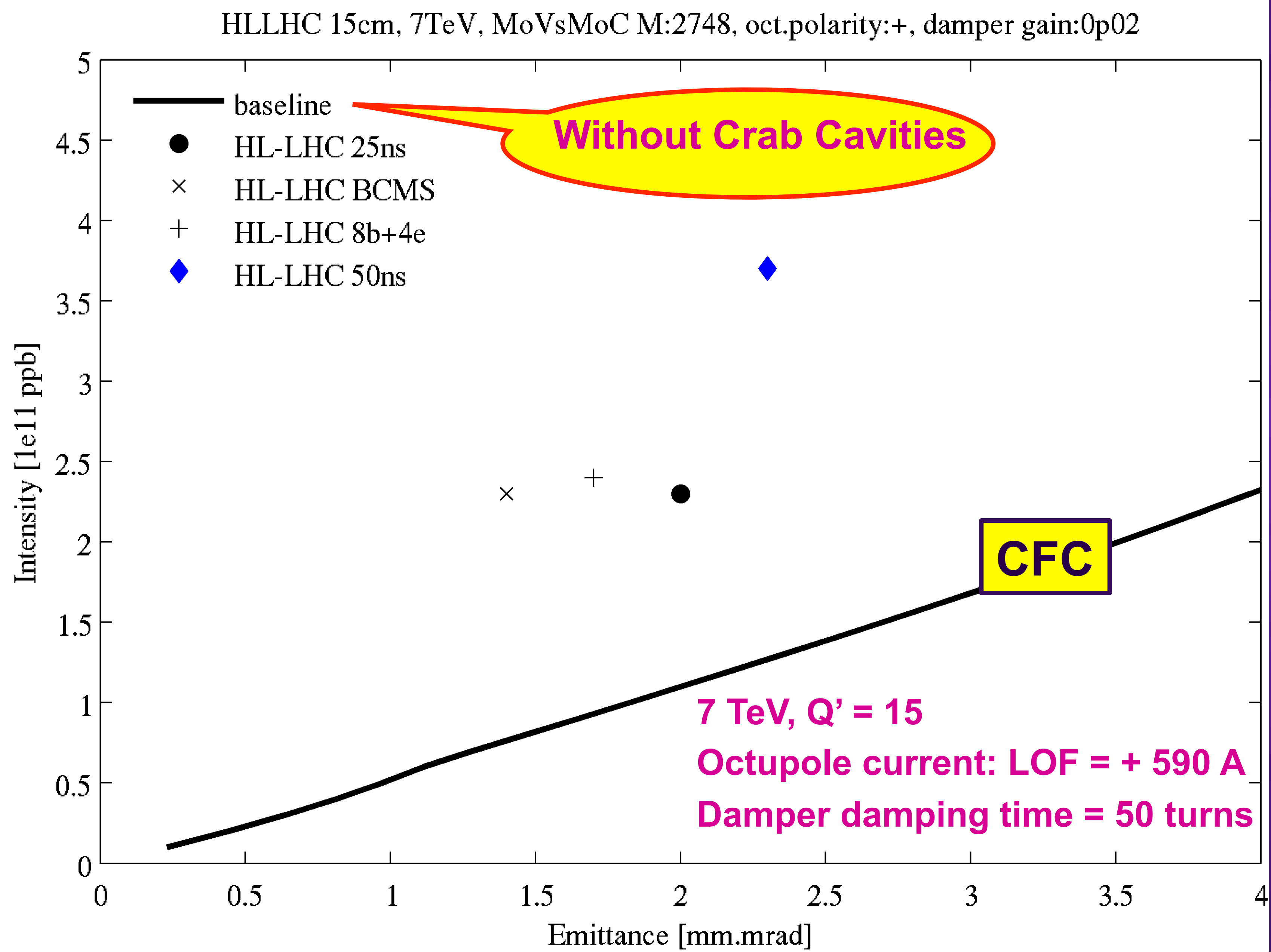
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



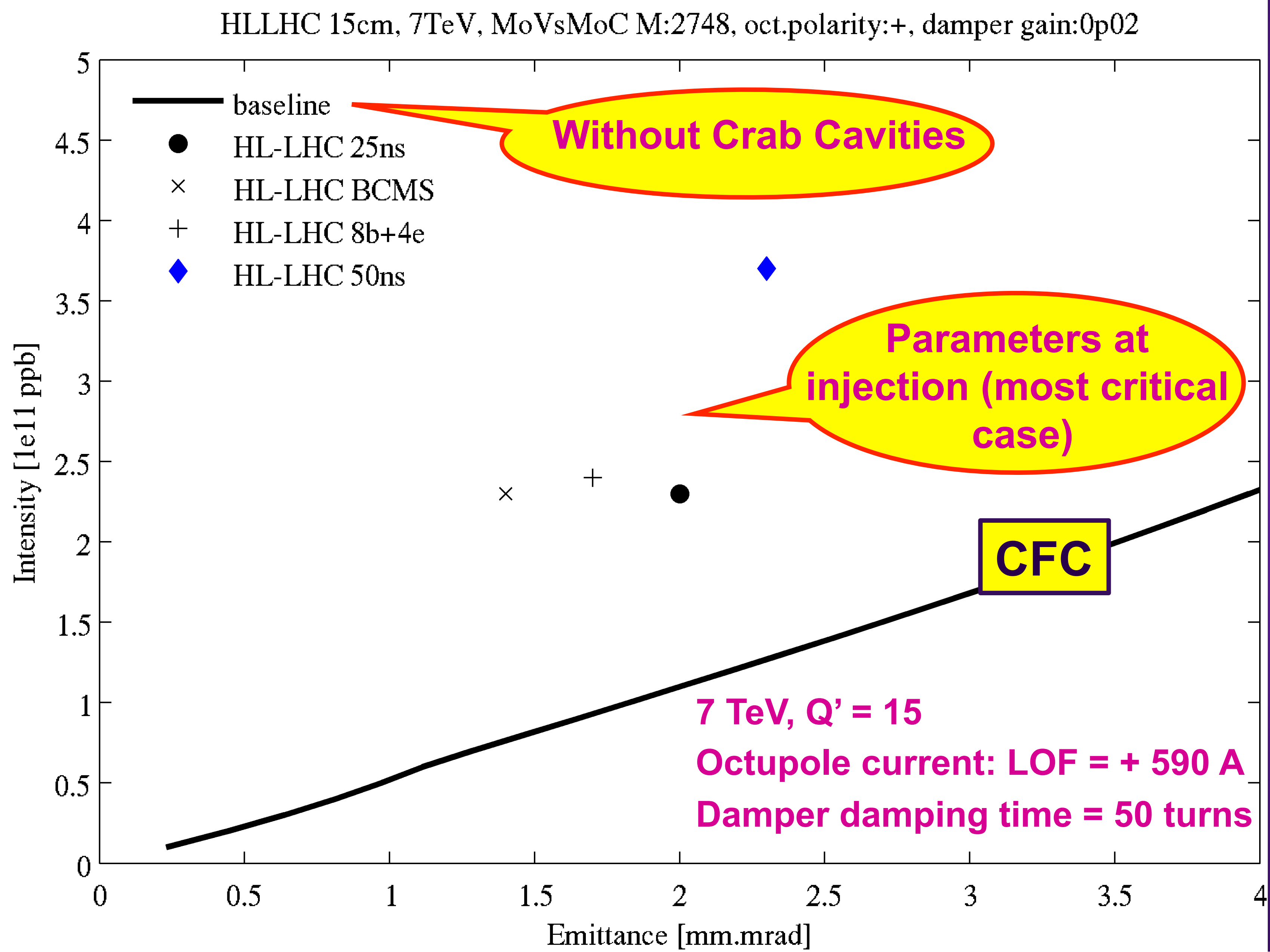
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



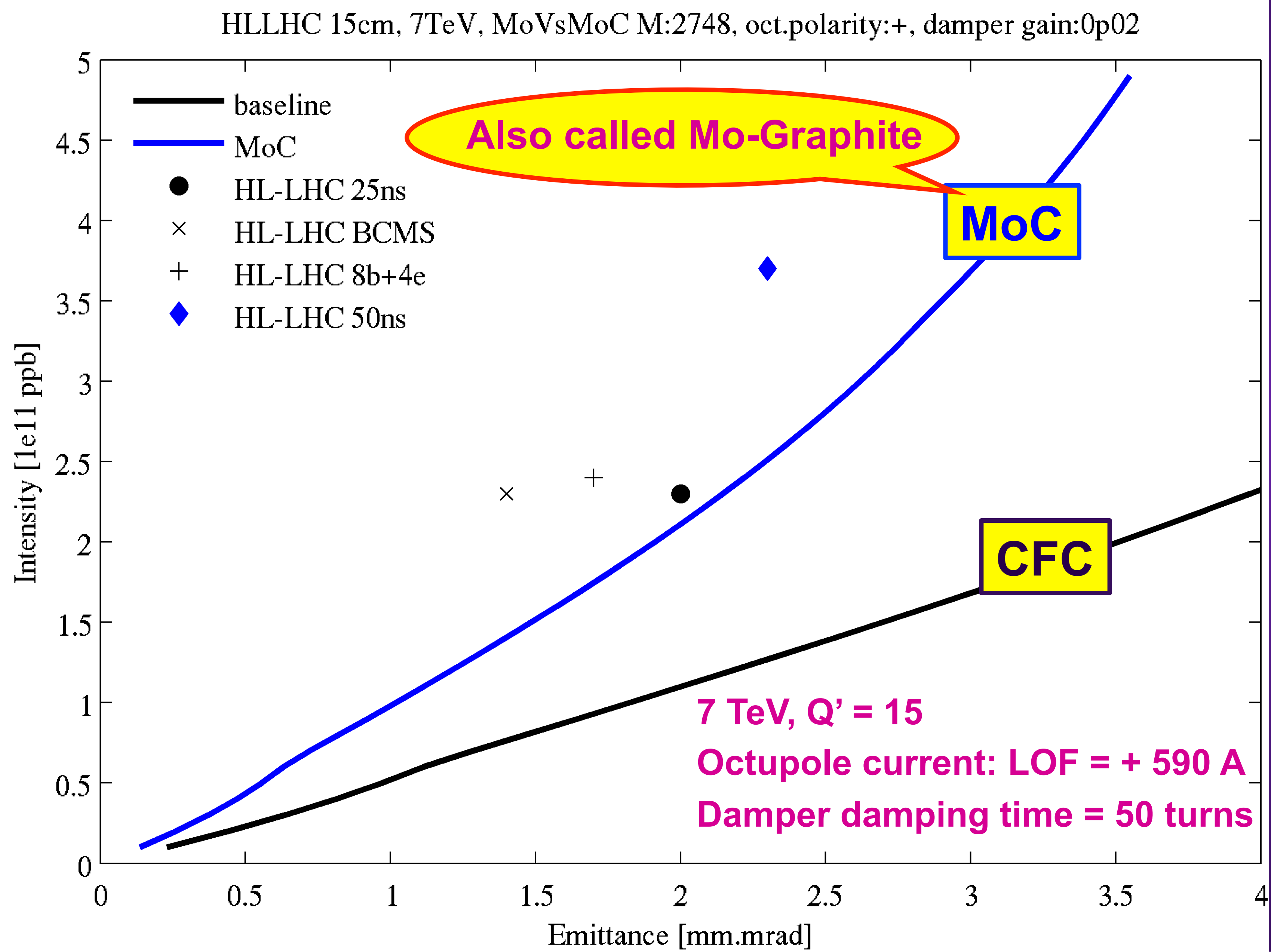
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



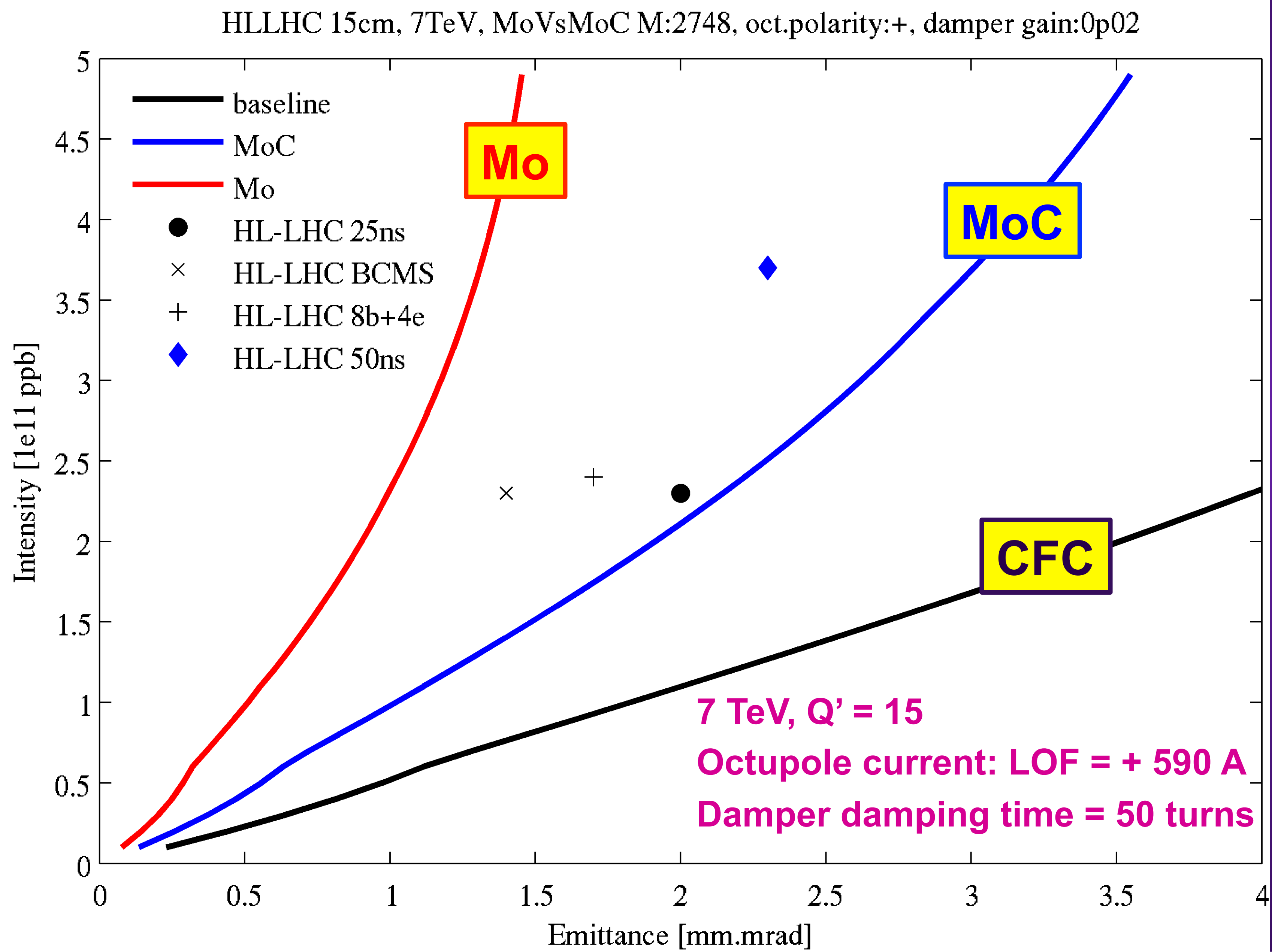
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)



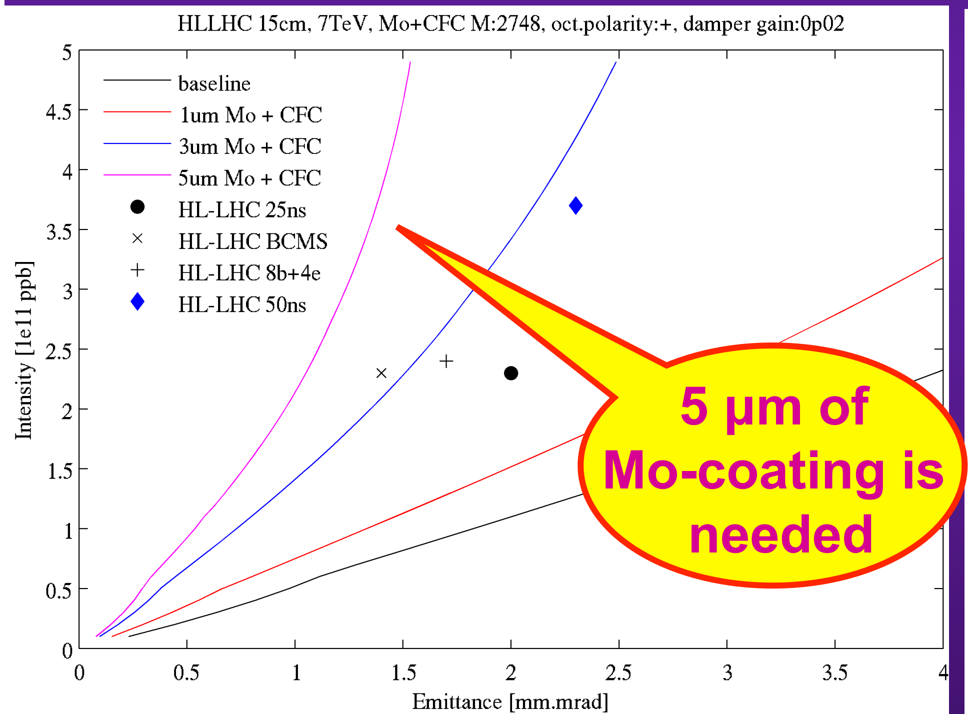
NEW MATERIAL NEEDED FOR THE COLLIMATORS (1/2)

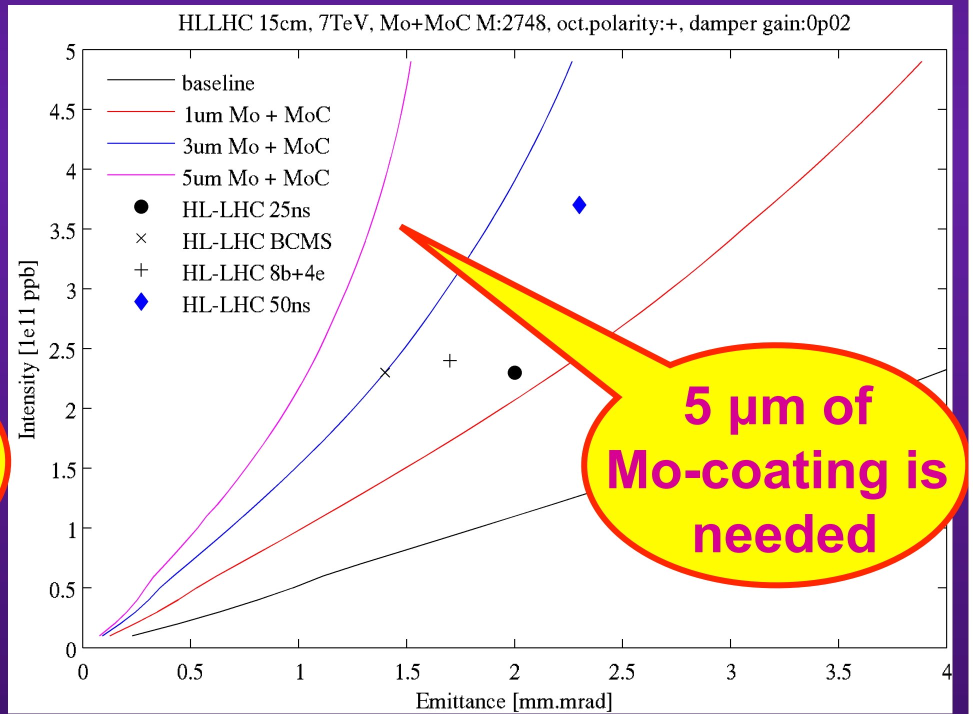


NEW MATERIAL NEEDED FOR THE COLLIMATORS (2/2)

Mo-coating on CFC collimators

Mo-coating on MoC collimators

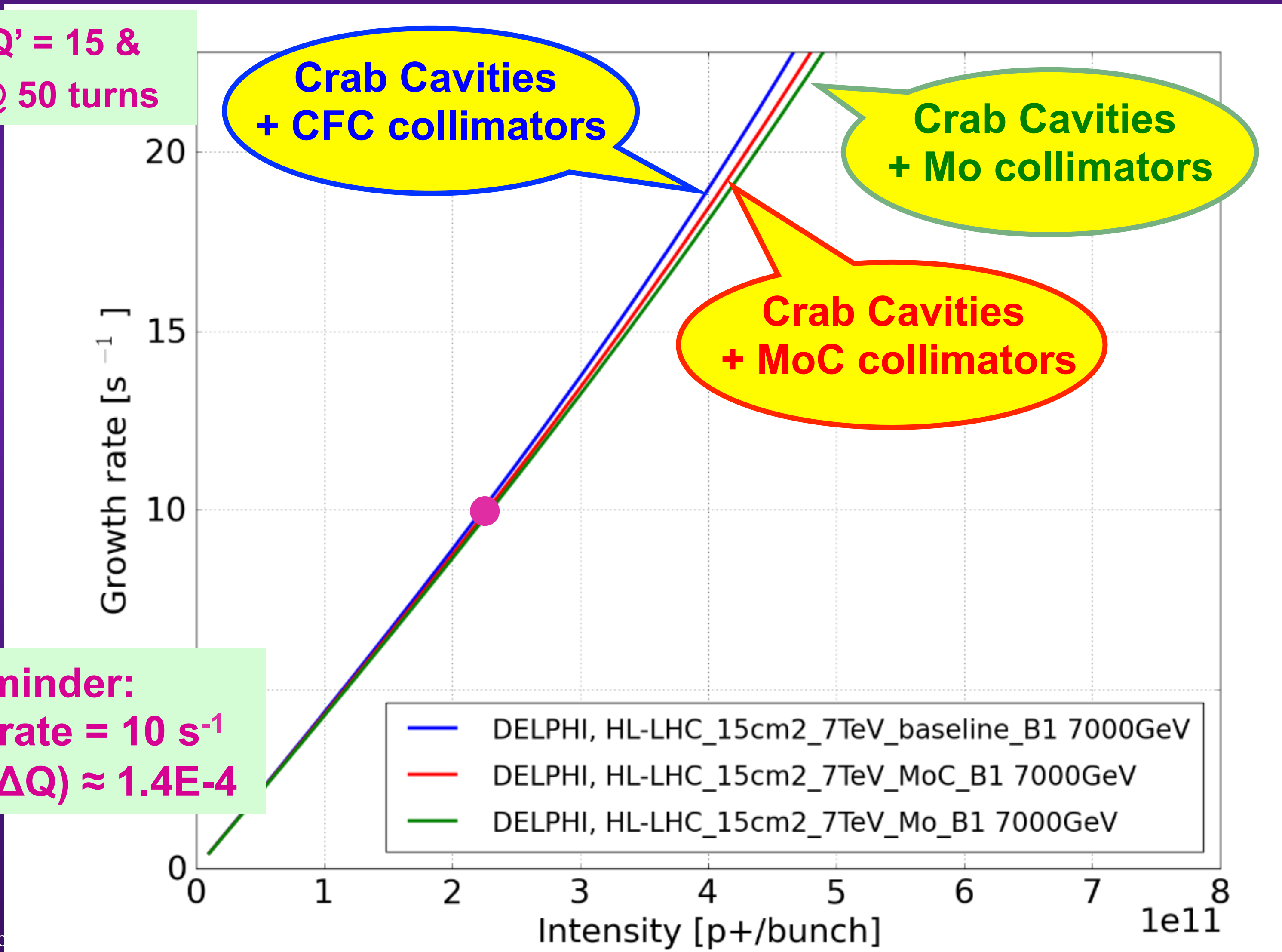




CRAB CAVITIES (1/6)

- Using the current list of HOMs (see N. Biancacci), the following results are obtained

DELPHI: Q' = 15 & damper @ 50 turns

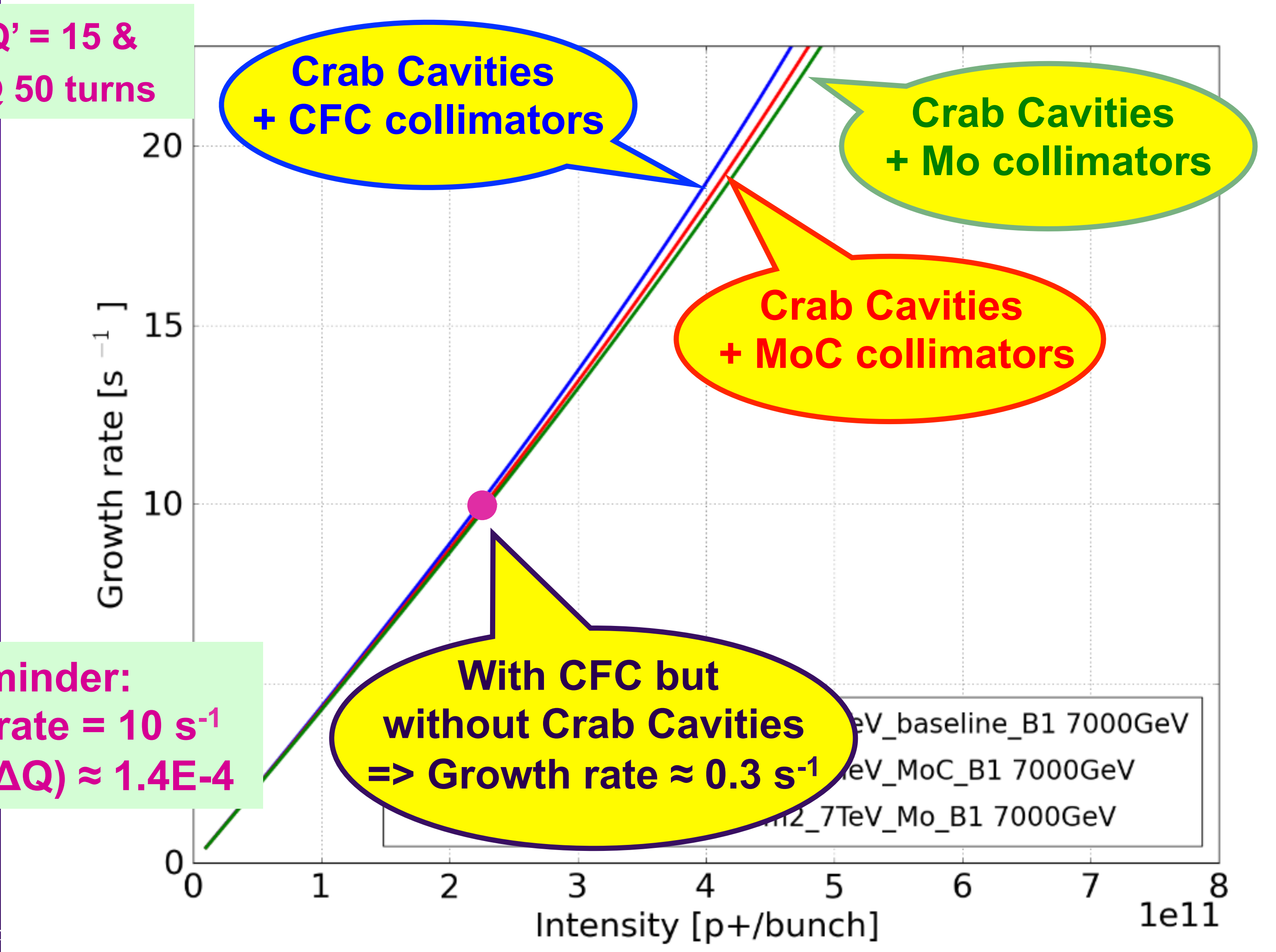


Reminder:
Growth rate = 10 s^{-1}
⇔ - Im (ΔQ) ≈ 1.4E-4

CRAB CAVITIES (1/6)

- **Using the current list of HOMs (see N. Biancacci), the following results are obtained**

DELPHI: Q' = 15 & damper @ 50 turns

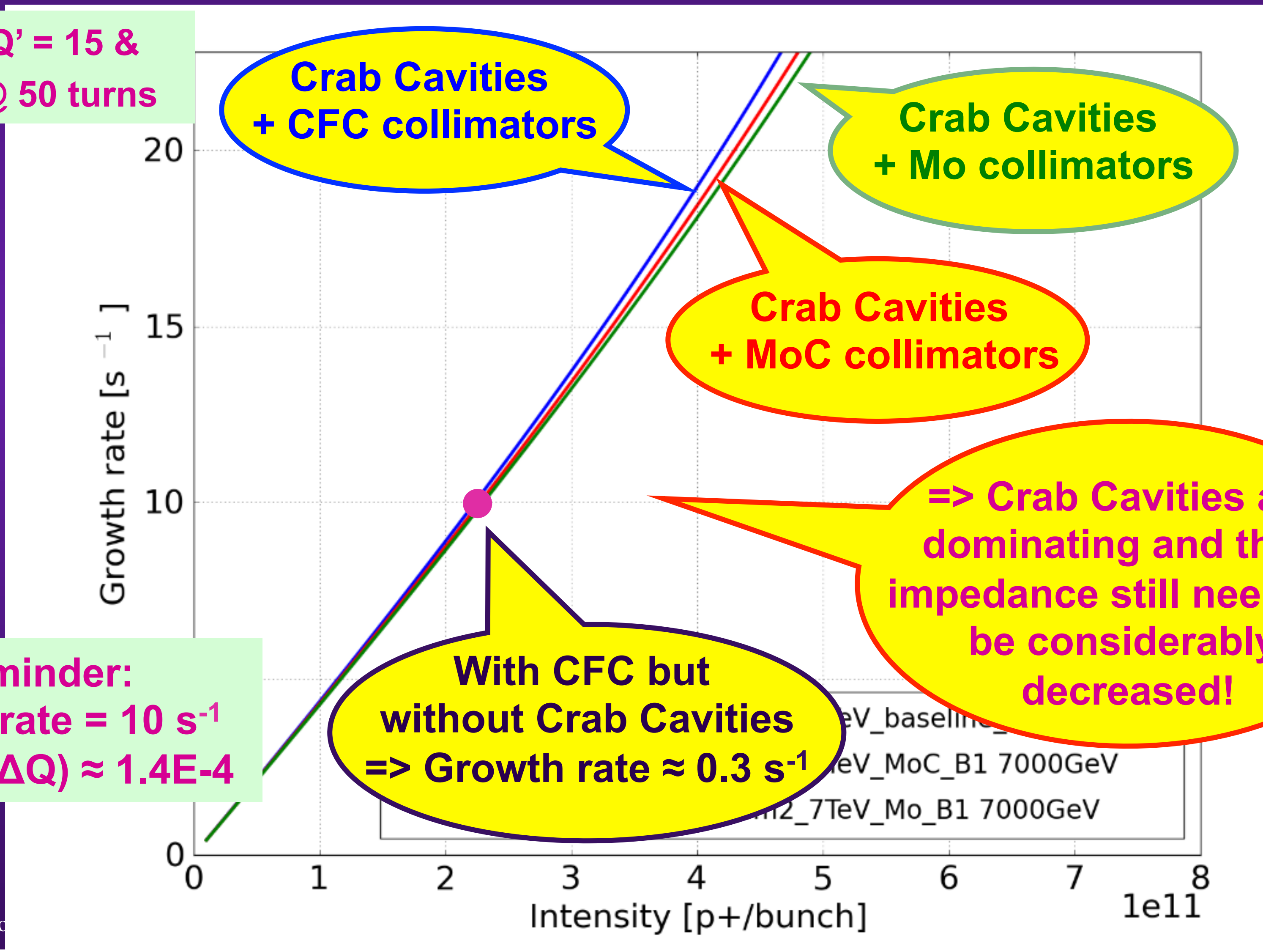


Reminder:
Growth rate = 10 s^{-1}
⇔ - Im (ΔQ) ≈ 1.4E-4

CRAB CAVITIES (1/6)

- Using the current list of HOMs (see N. Biancacci), the following results are obtained

DELPHI: Q' = 15 & damper @ 50 turns



Reminder:
Growth rate = 10 s^{-1}
⇔ - Im (ΔQ) ≈ 1.4E-4

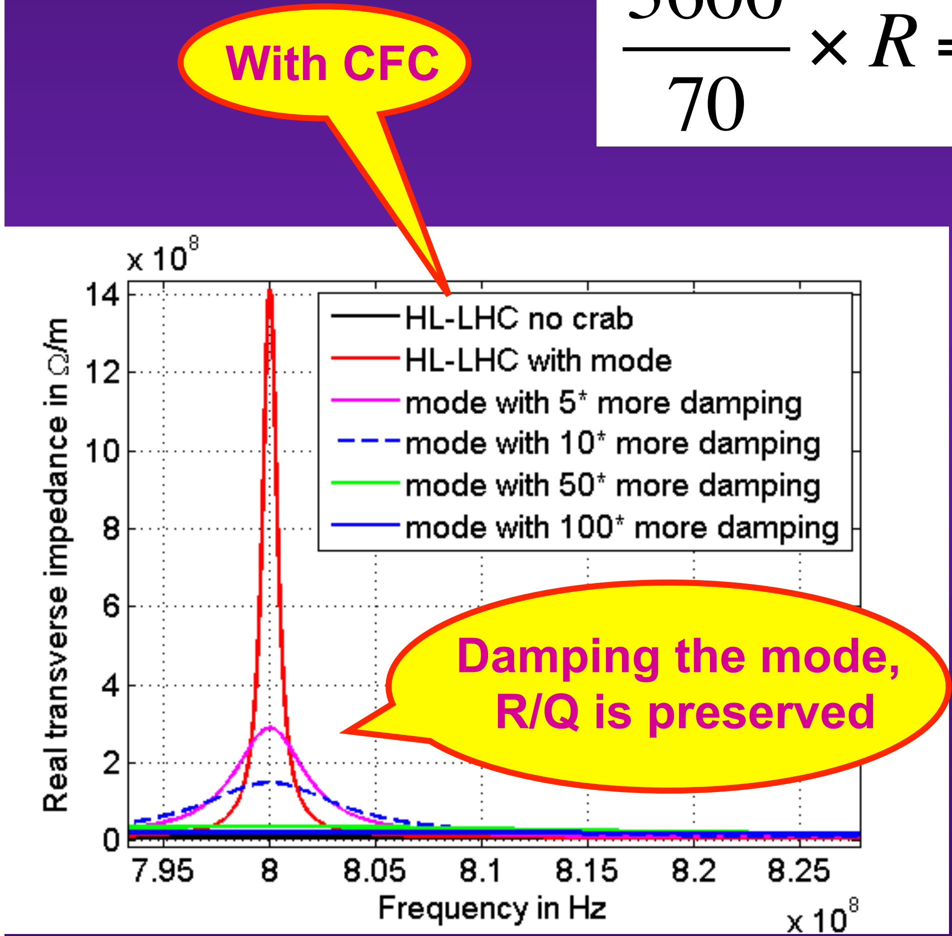
CRAB CAVITIES (2/6)

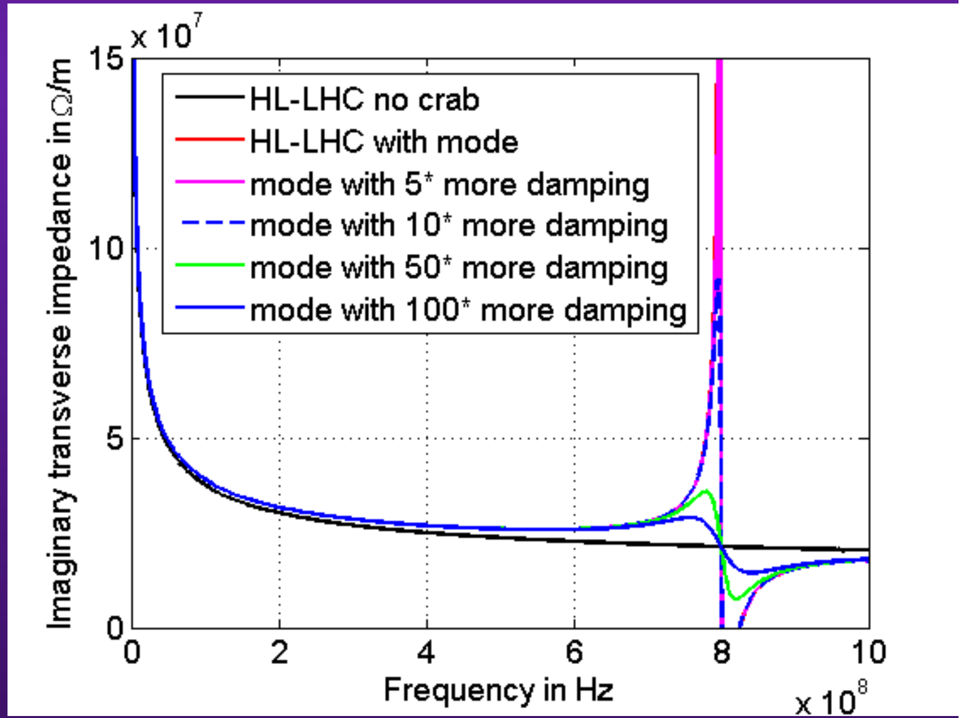
- Considering only the following mode (already studied in the past and close to critical modes from the list shown by N. Biancacci)

$$\frac{3600}{70} \times R = 1.4 \text{ G}\Omega/\text{m}$$

$$f_r = 800 \text{ MHz}$$

$$Q = 1000$$

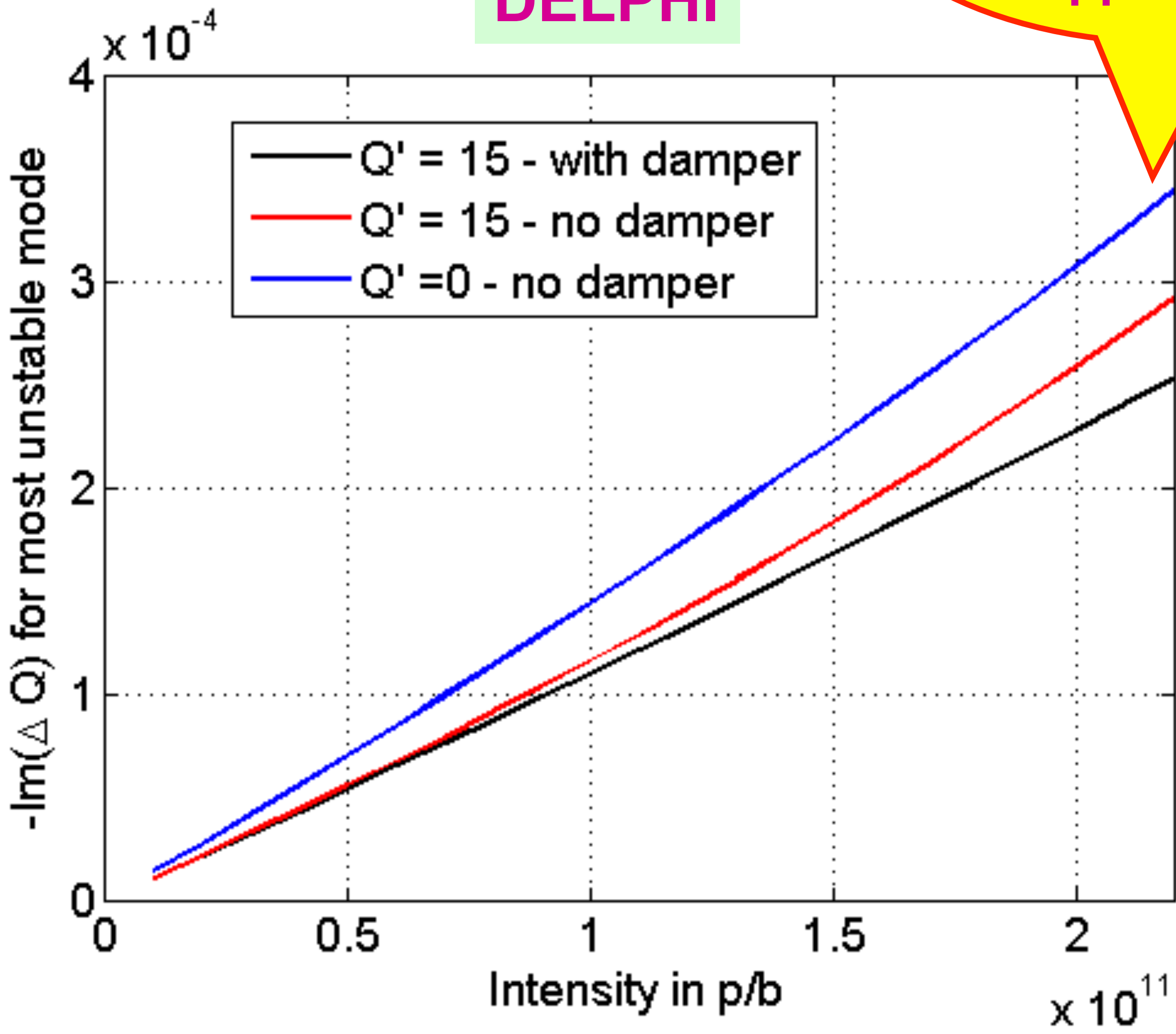




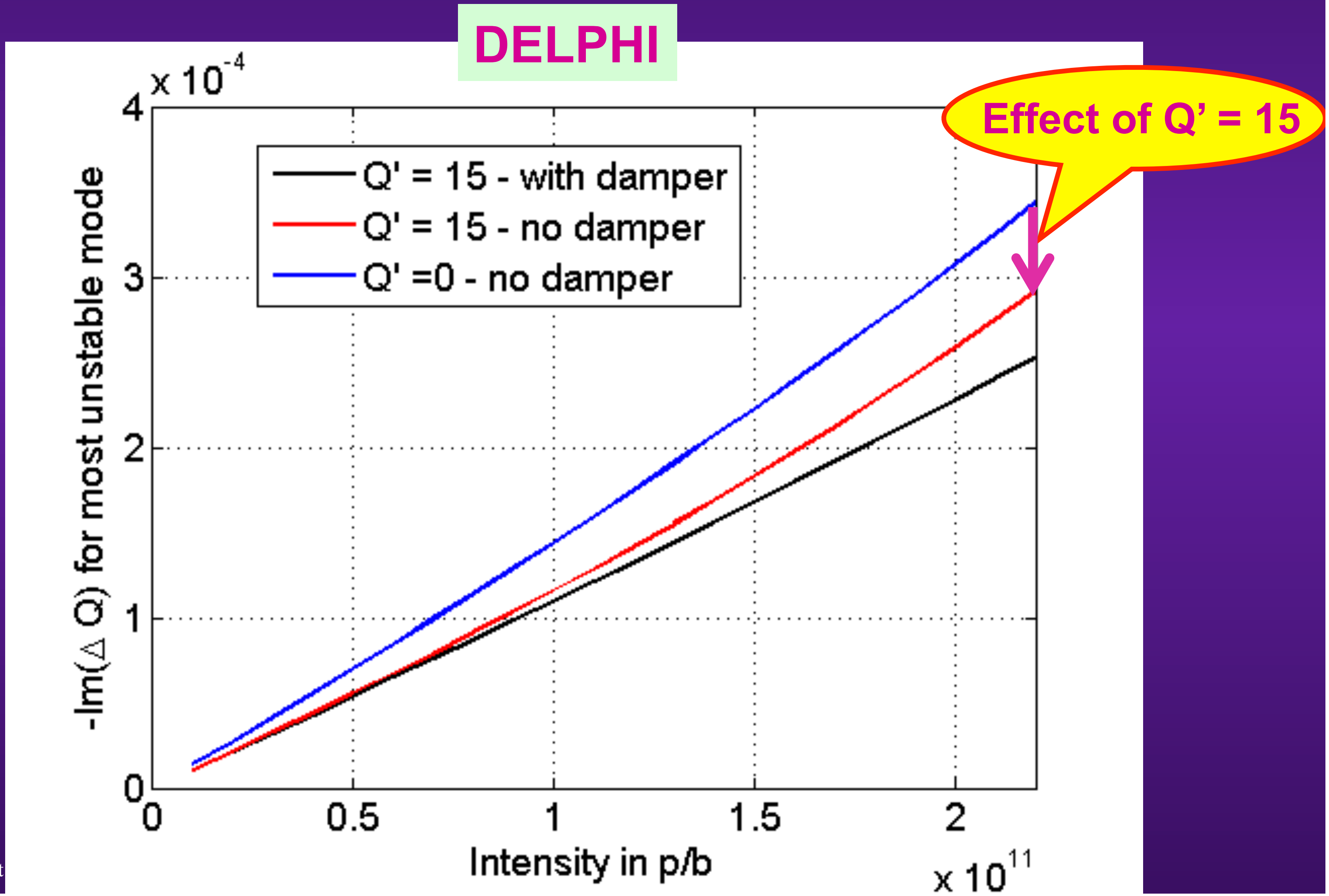
CRAB CAVITIES (3/6)

- Im (ΔQ) ≈ 3.4E-4
⇔ Growth rate = 24 s^{-1}
(in agreement with a previous estimate, see Appendix)

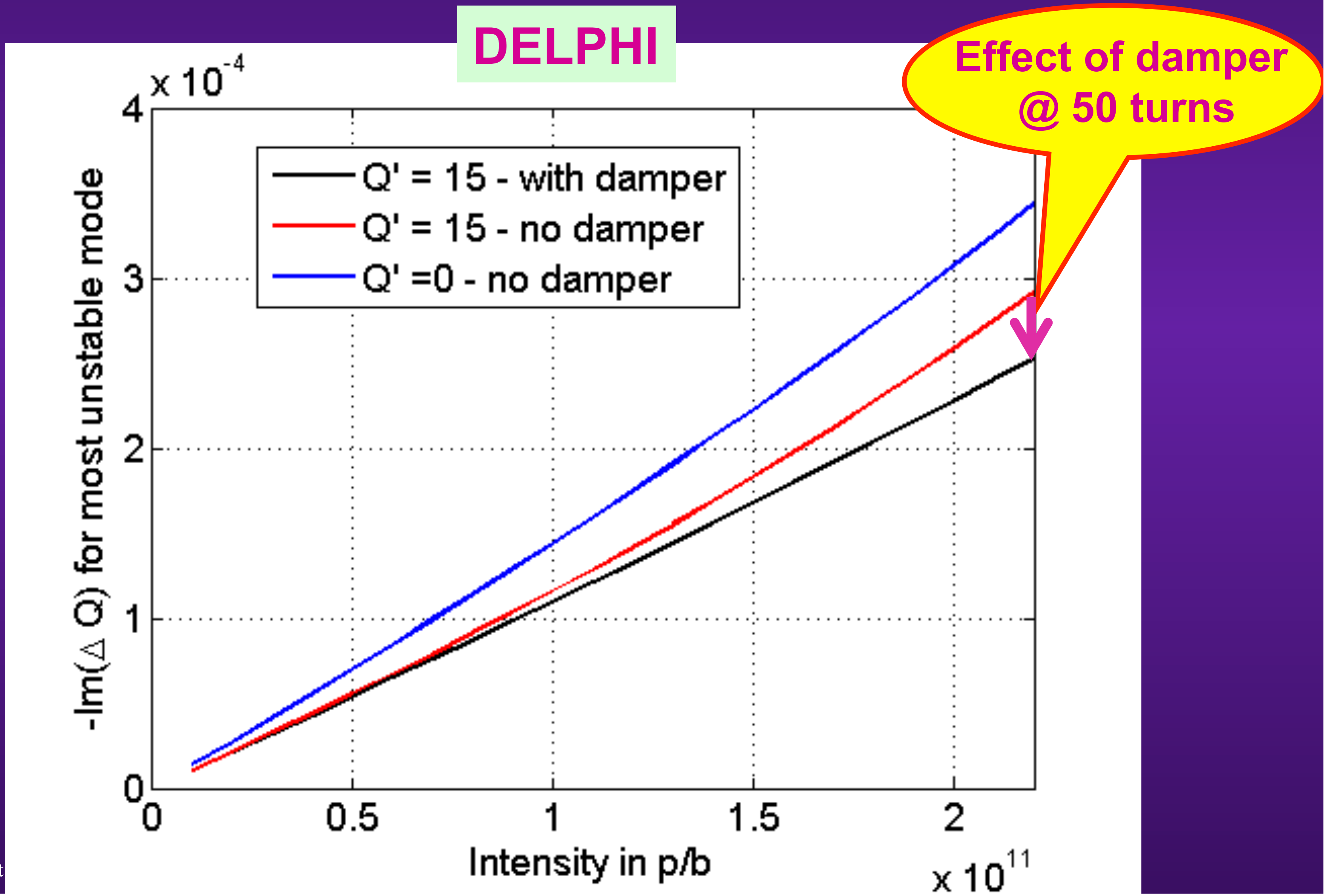
DELPHI



CRAB CAVITIES (3/6)

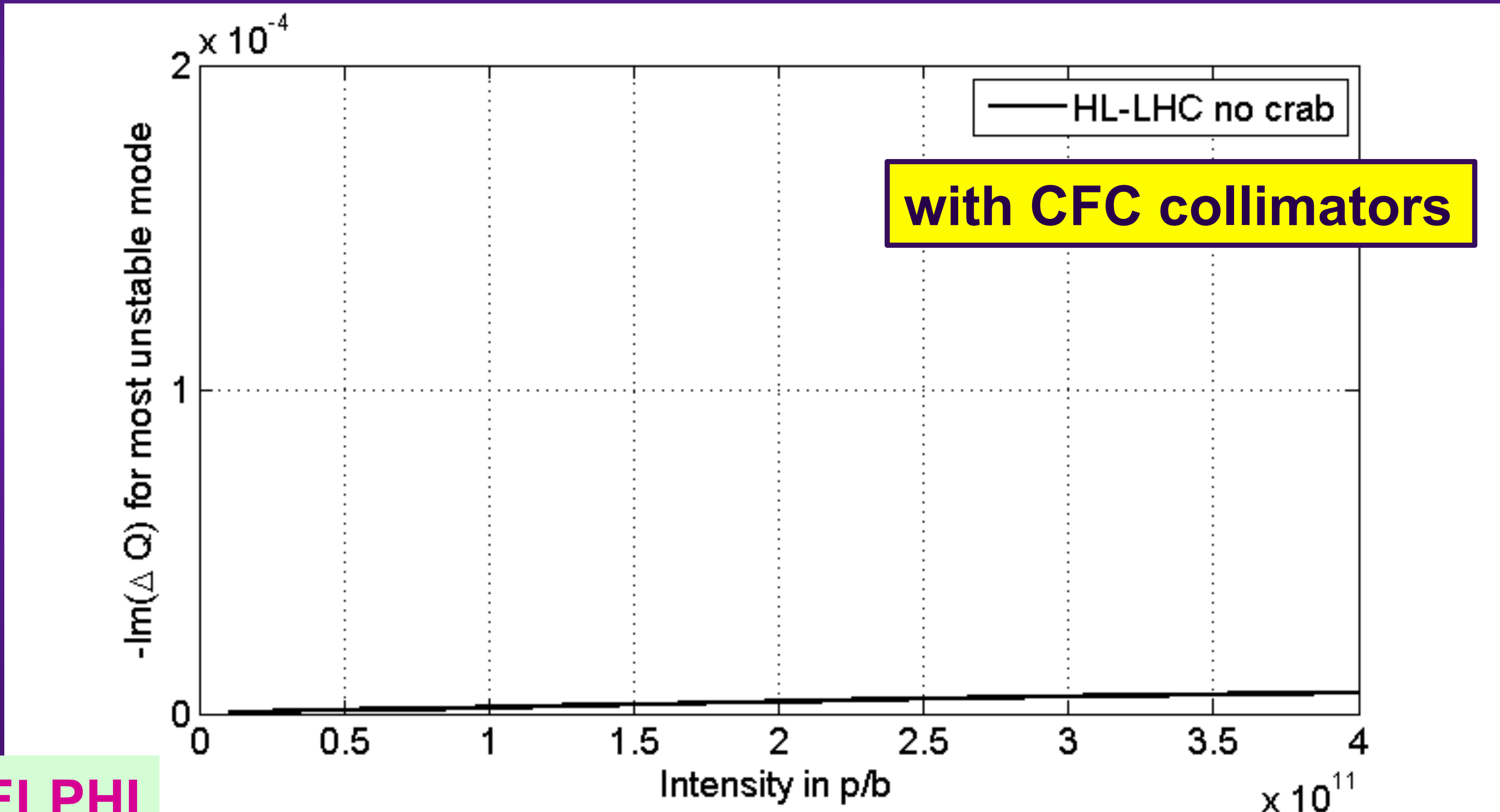


CRAB CAVITIES (3/6)



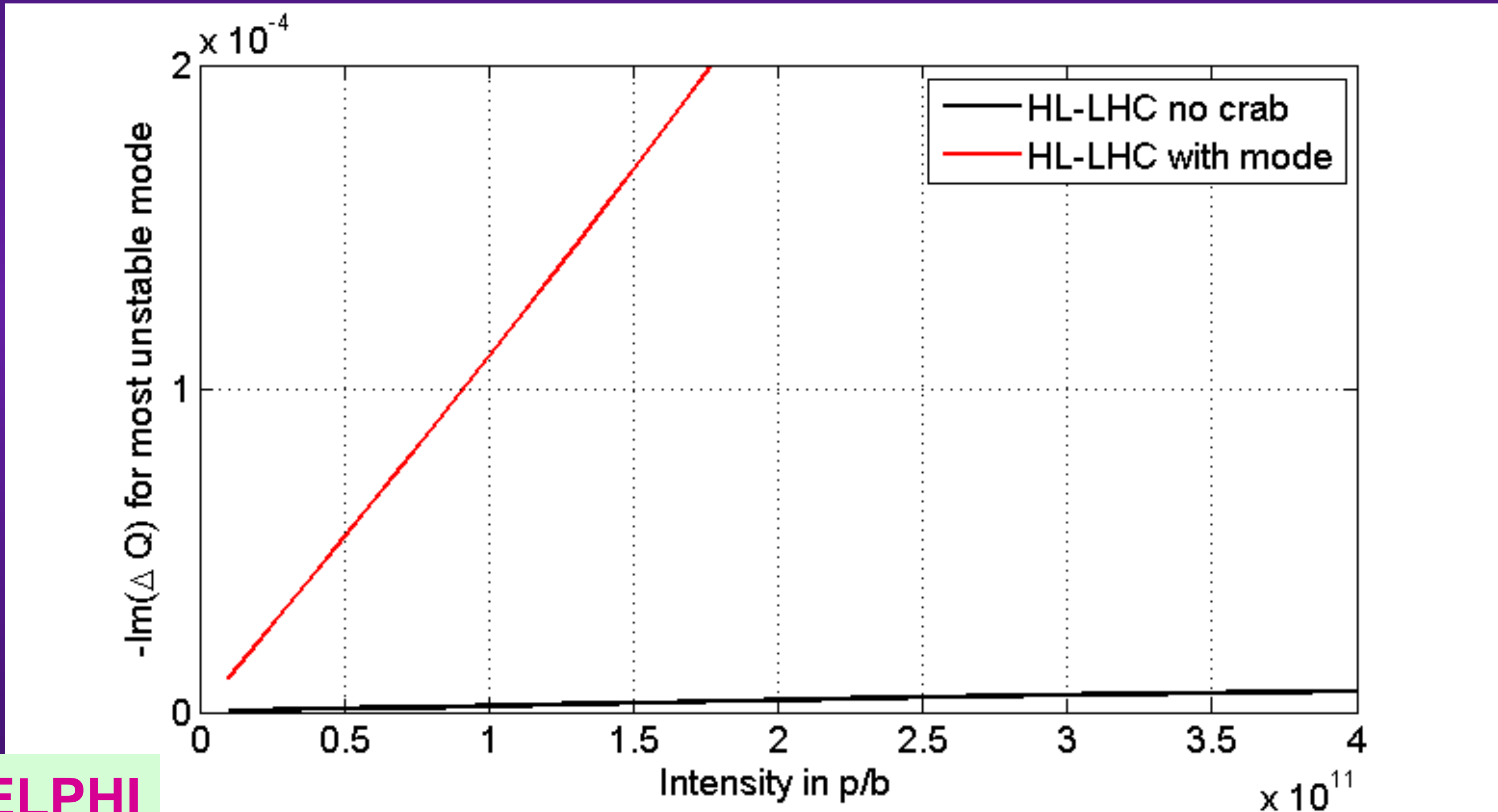
CRAB CAVITIES (4/6)

- **What is the effect of such a HOM compared to the rest of the HL-LHC impedance model (with Q' = 15 & damper @ 50 turns)?**



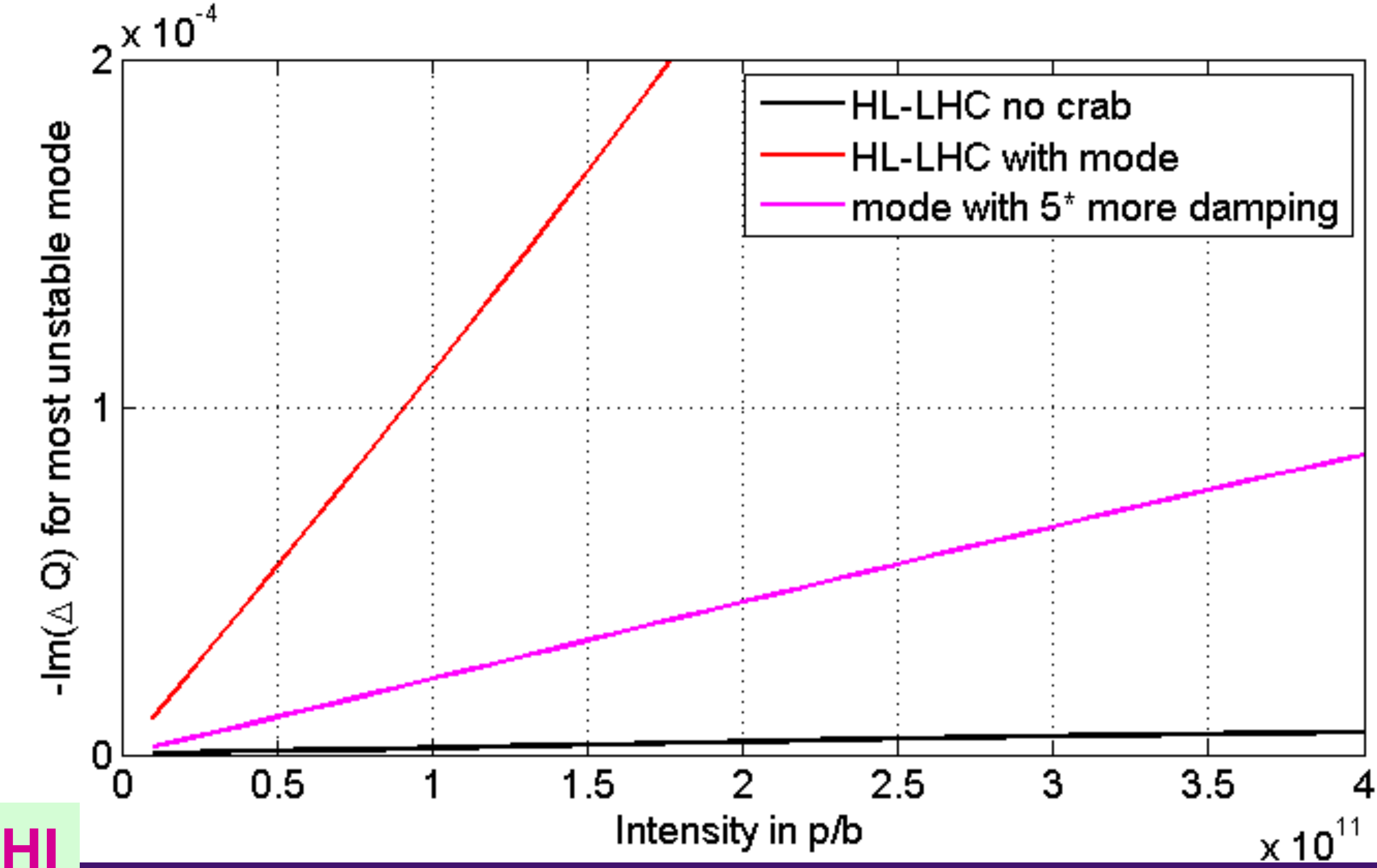
DELPHI

CRAB CAVITIES (4/6)



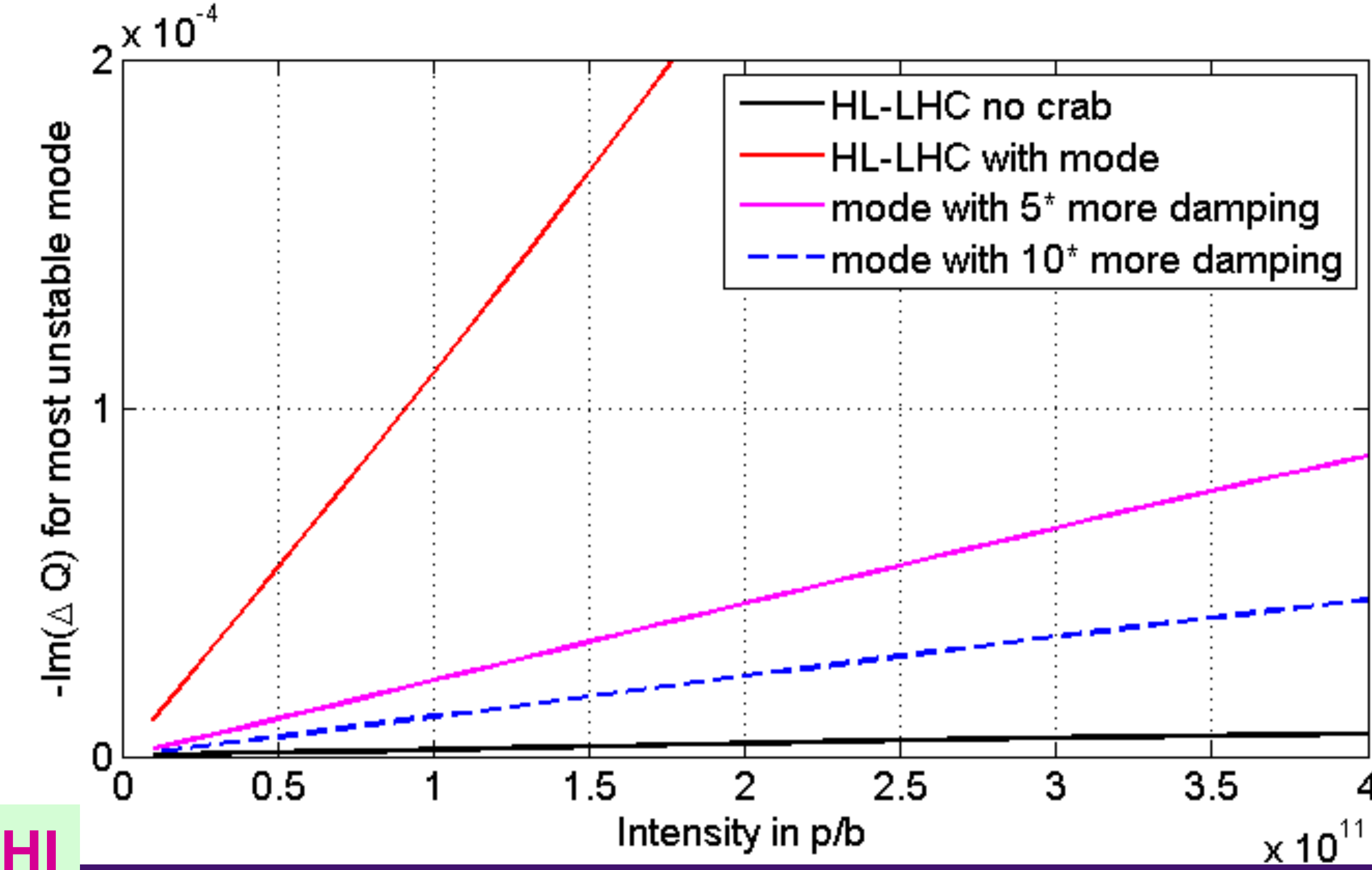
DELPHI

CRAB CAVITIES (4/6)



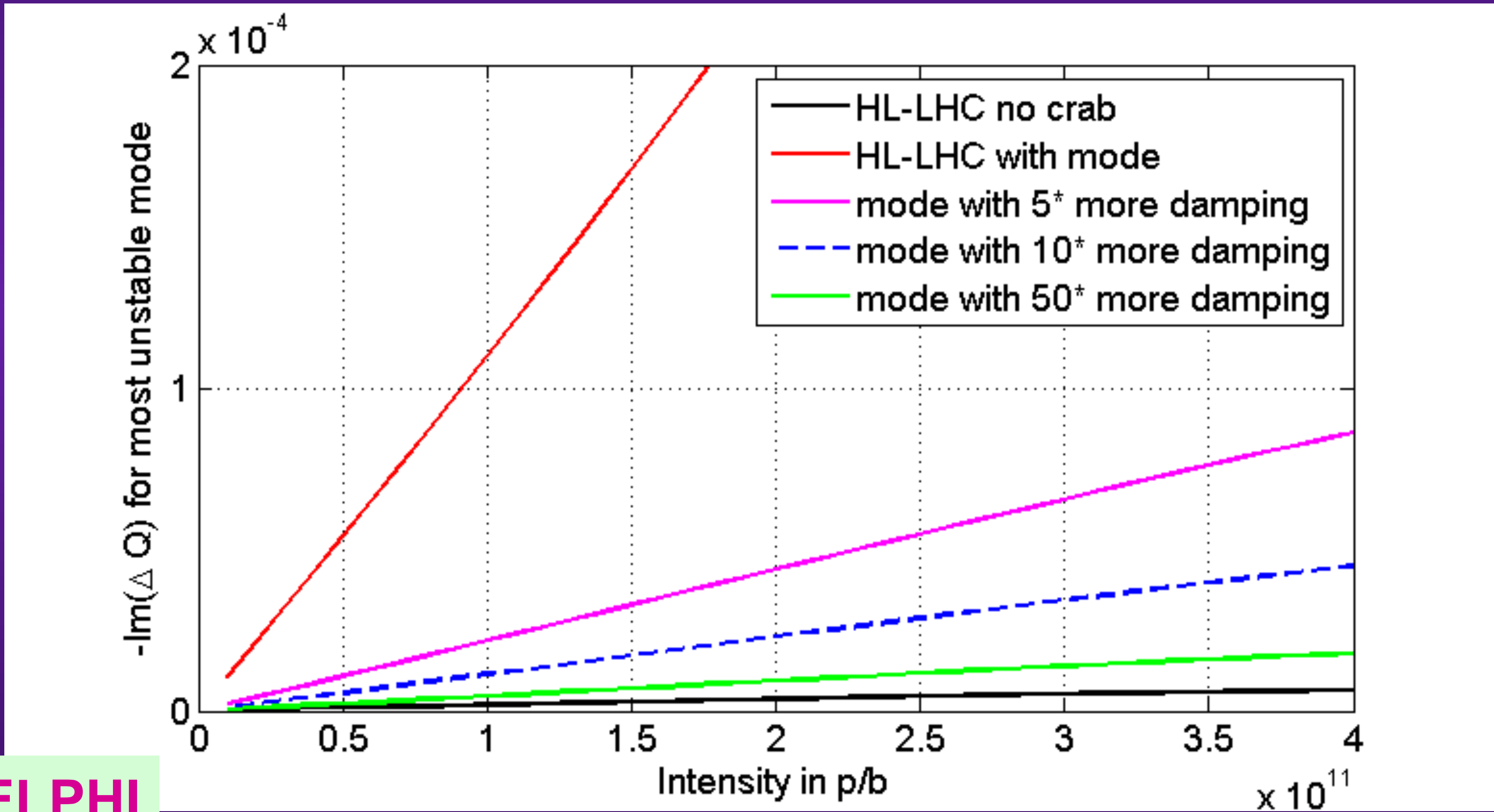
DELPHI

CRAB CAVITIES (4/6)



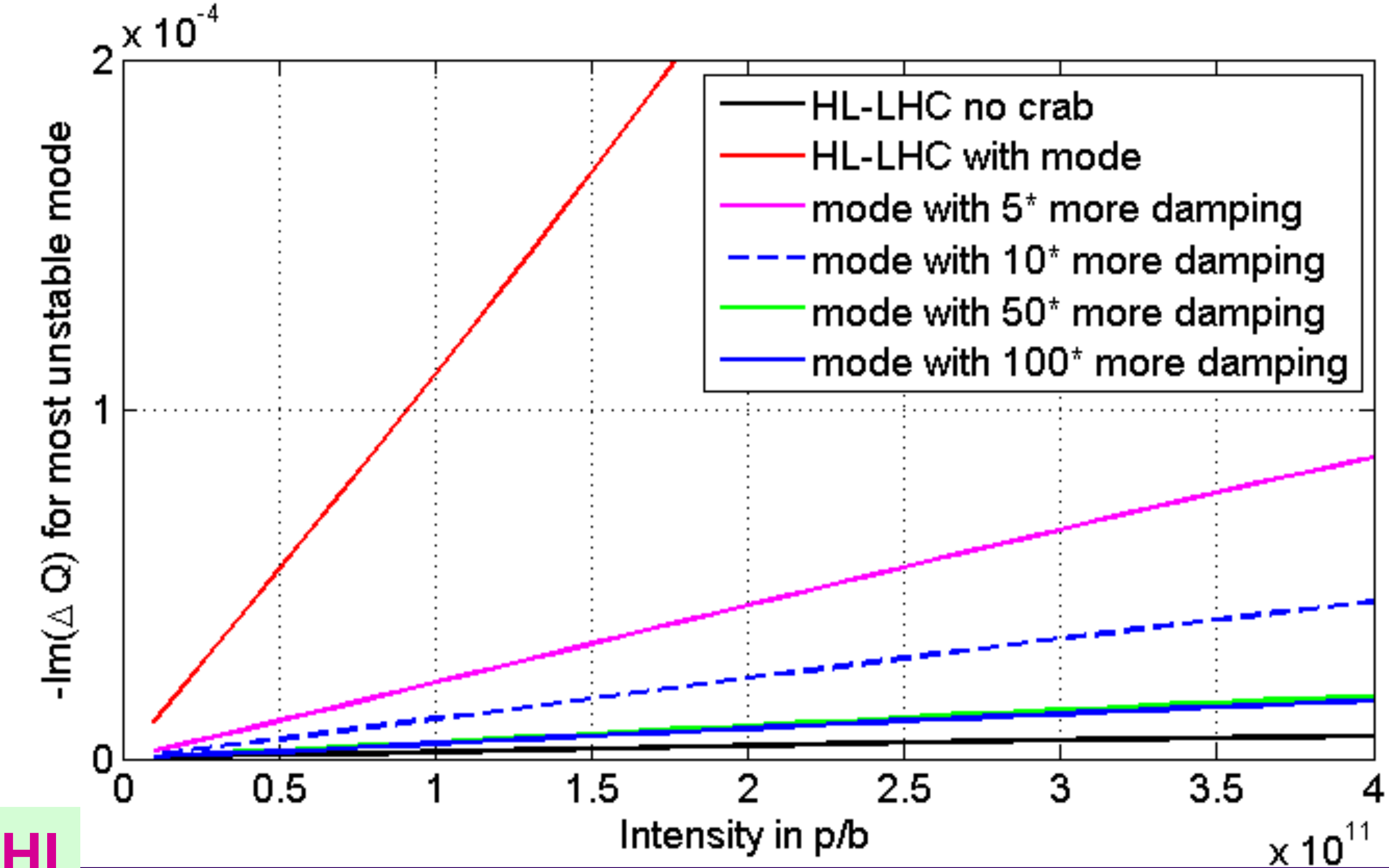
DELPHI

CRAB CAVITIES (4/6)



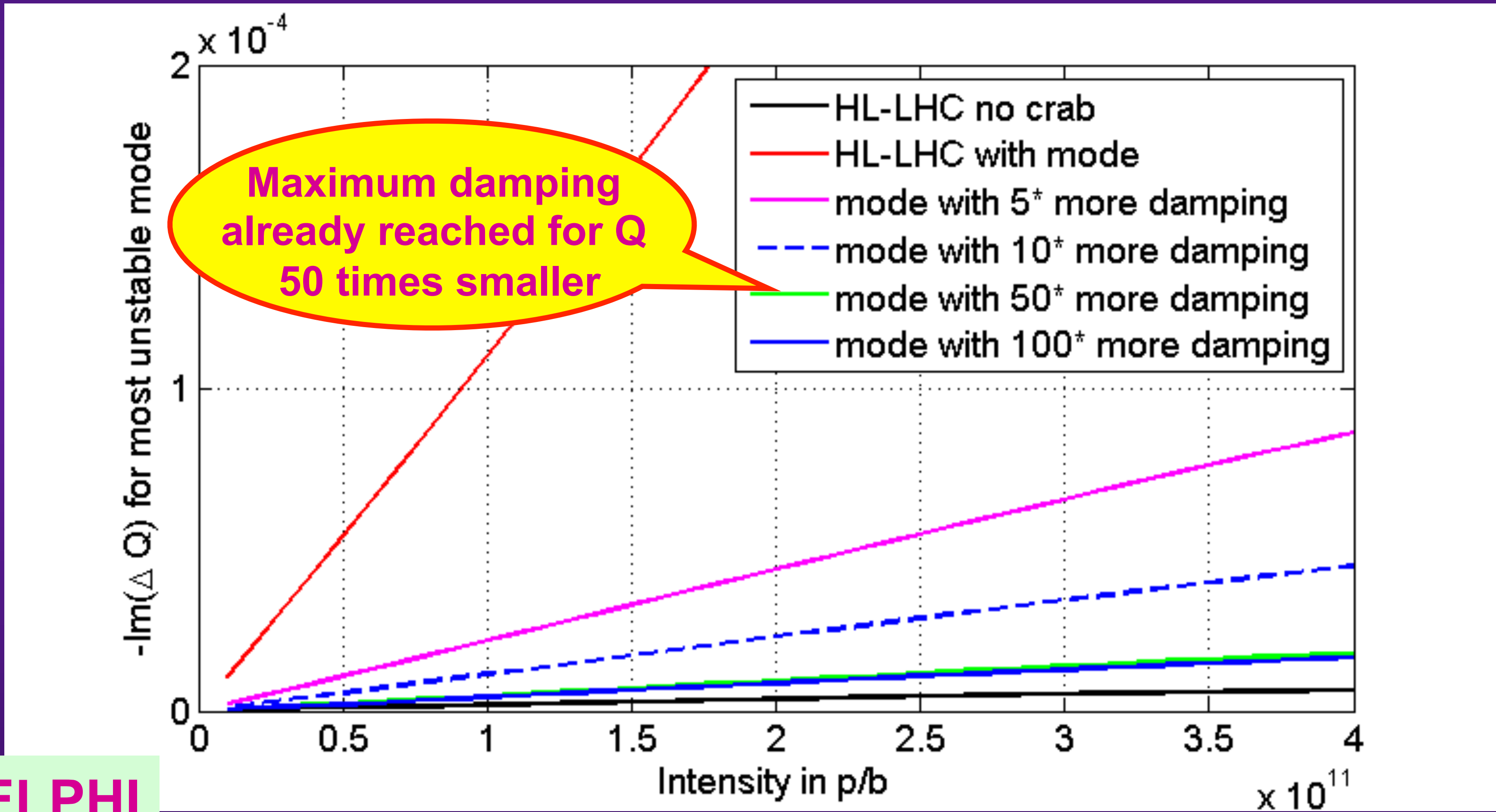
DELPHI

CRAB CAVITIES (4/6)



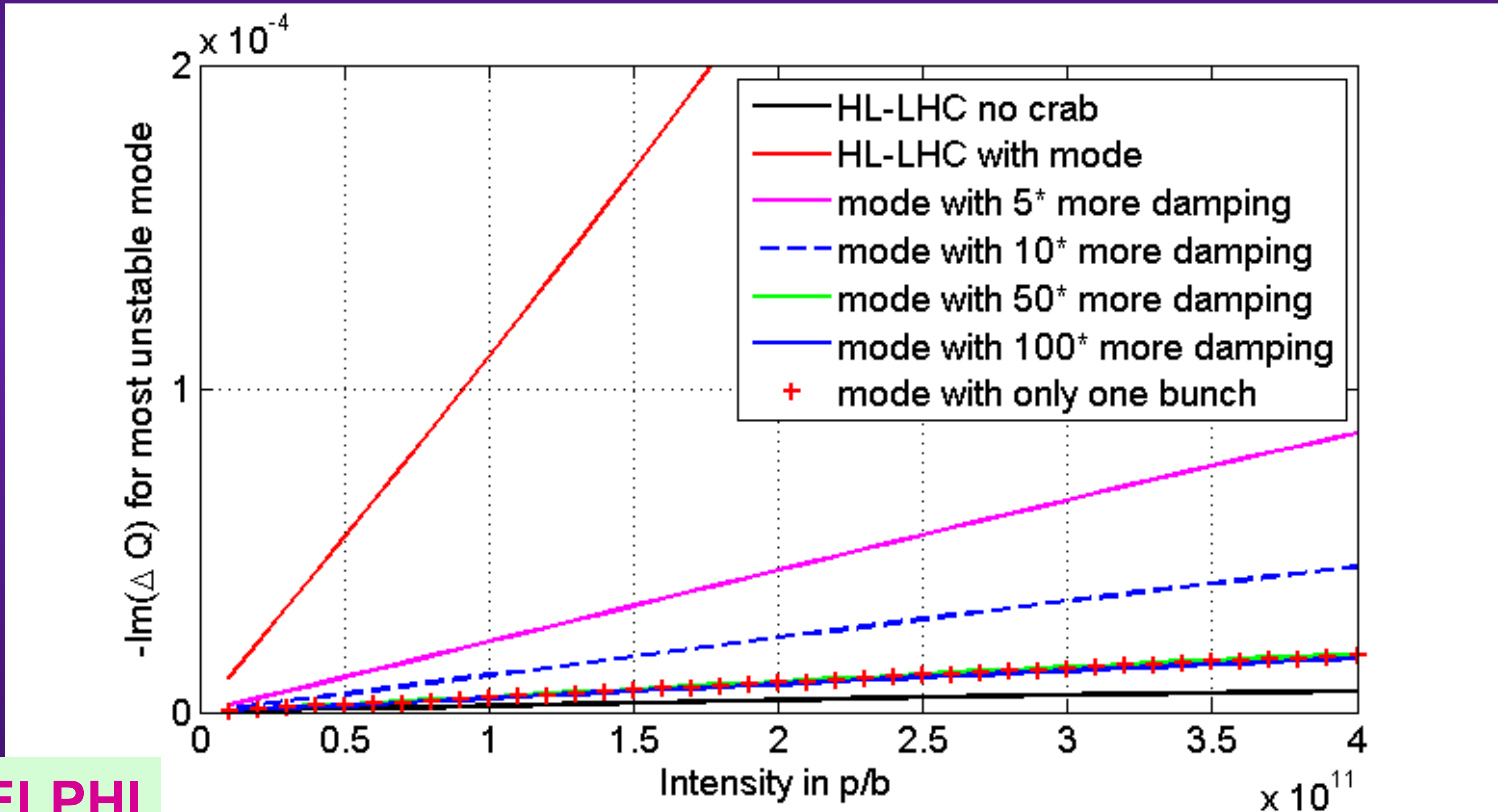
DELPHI

CRAB CAVITIES (4/6)



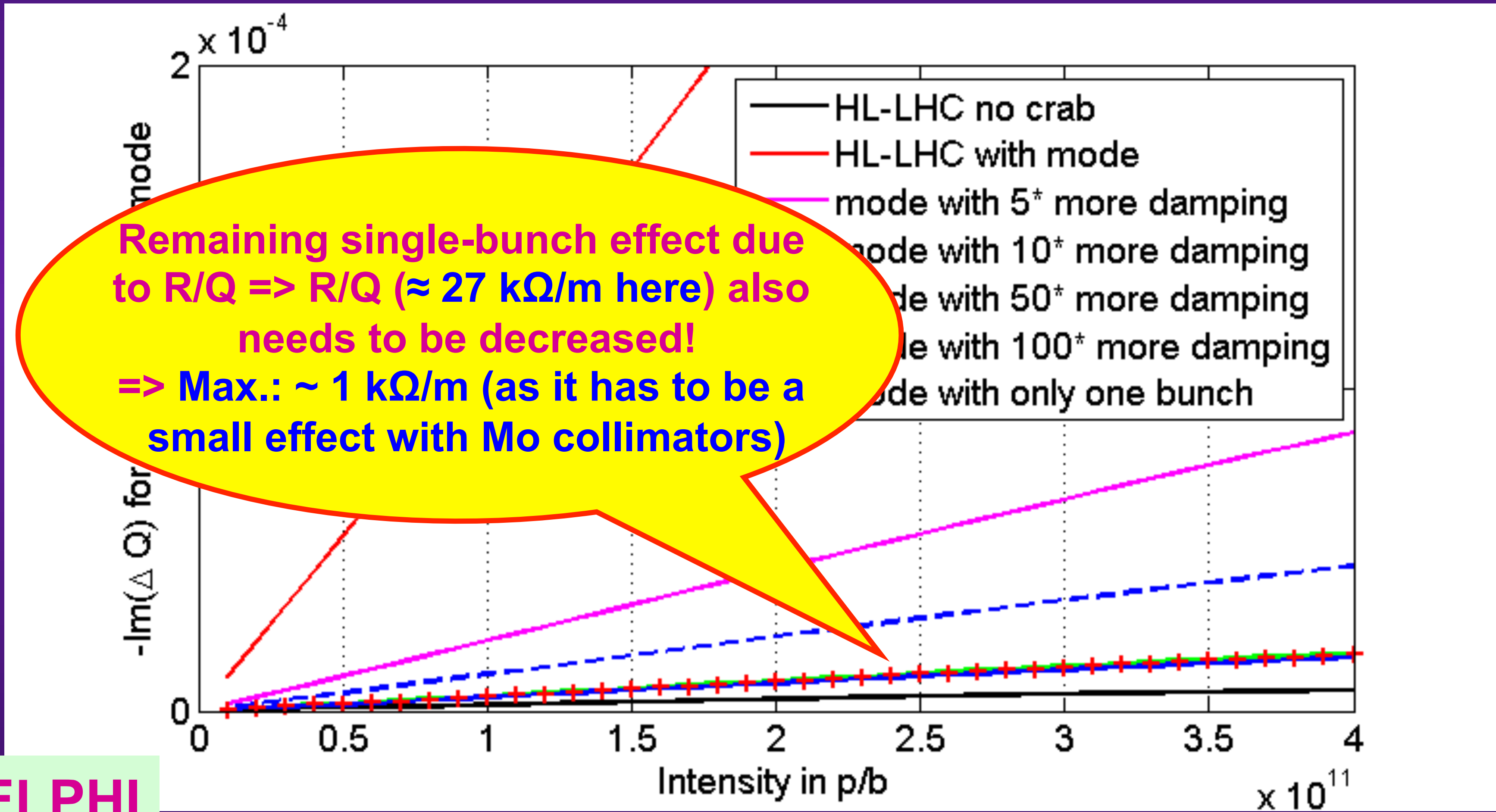
DELPHI

CRAB CAVITIES (4/6)



DELPHI

CRAB CAVITIES (4/6)



DELPHI

CRAB CAVITIES (5/6)

- **Conclusion: Despite the huge effort to optimize the Crab Cavities design (many thanks!), some HOMs are still too high**

- **2 conditions should be satisfied**

  - **1)** $$R_{HOM\,/\,CC}^{\max} \approx 10 - 20 \text{ k}\Omega/\text{m}$$

  - **2)** $$\left(\frac{R}{Q}\right)_{\text{All CC}}^{\max} \approx \text{few k}\Omega/\text{m}$$

See N. Biancacci (or Appendix)

Could be 8 (N_{CC} / plane) higher if the HOMs of all the cavities are not at the same f_r => ~ 160 kΩ/m

To be confirmed with HEADTAIL simulations

CRAB CAVITIES (6/6)

- HOWEVER, it is true that the beta functions will increase to maximum values only while in collision (with β* leveling)

CRAB CAVITIES (6/6)

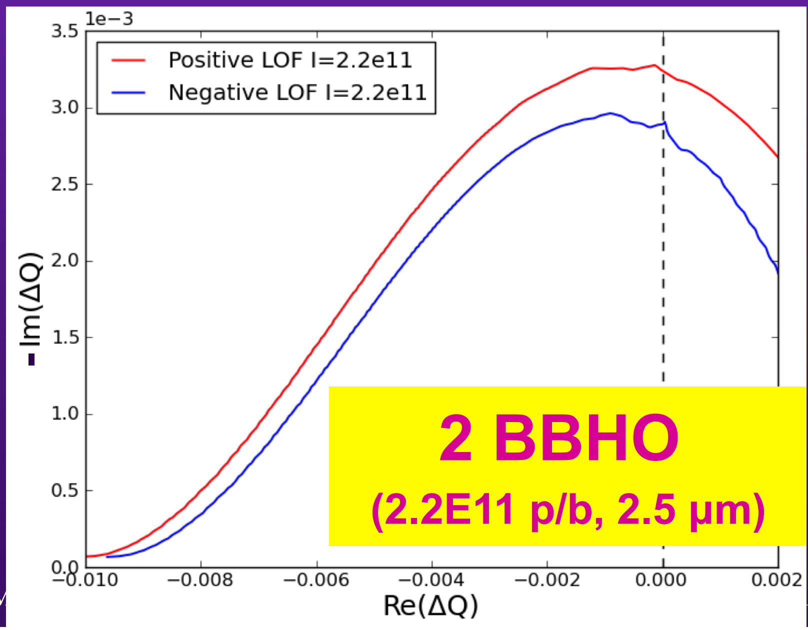
- HOWEVER, it is true that the beta functions will increase to maximum values only while in collision (with β* leveling)
  - Collisions in IP1 and IP5 should start at β* = 70 cm (instead of 15 cm) for lumi reason => ~ 70 / 15 ≈ 4.7 times smaller beta functions at Crab Cavities

    => Previous limits can be increased by factor ~ 5 (~ 0.8 MΩ/m)

CRAB CAVITIES (6/6)

- HOWEVER, it is true that the beta functions will increase to maximum values only while in collision (with β* leveling)
  - Collisions in IP1 and IP5 should start at β* = 70 cm (instead of 15 cm) for lumi reason => ~ 70 / 15 ≈ 4.7 times smaller beta functions at Crab Cavities

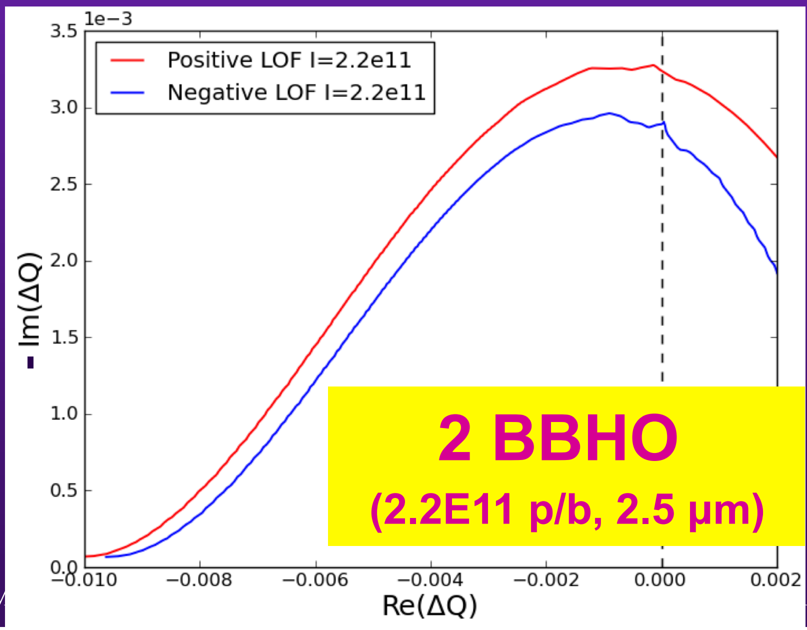
    => Previous limits can be increased by factor ~ 5 (~ 0.8 MΩ/m)
  - Once in collisions in IP1 and IP5, ~ 30 times more Landau damping due to Beam-Beam Head-On (BBHO)



CRAB CAVITIES (6/6)

- HOWEVER, it is true that the beta functions will increase to maximum values only while in collision (with β* leveling)
  - Collisions in IP1 and IP5 should start at β* = 70 cm (instead of 15 cm) for lumi reason => ~ 70 / 15 ≈ 4.7 times smaller beta functions at Crab Cavities

    => Previous limits can be increased by factor ~ 5 (~ 0.8 MΩ/m)
  - Once in collisions in IP1 and IP5, ~ 30 times more Landau damping due to Beam-Beam Head-On (BBHO)

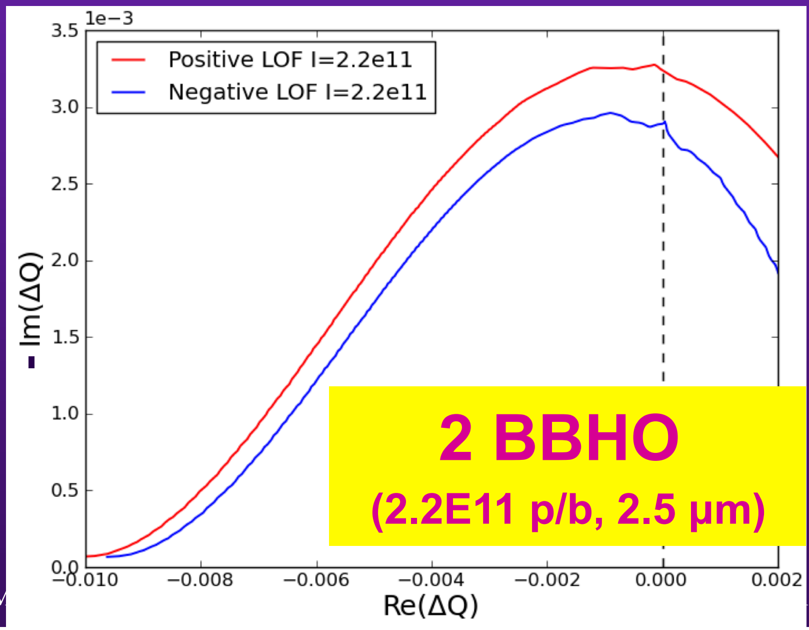


=> Previous limits can be increased by factor ~ 30 => Could therefore help to collide even earlier if impedance of Crab Cavities cannot be reduced sufficiently

CRAB CAVITIES (6/6)

- **HOWEVER, it is true that the beta functions will increase to maximum values only while in collision (with β* leveling)**
  - **Collisions in IP1 and IP5 should start at β* ≈ 70 cm (instead of 15 cm) for lumi reason => ~ 70 / 15 ≈ 4.7 times smaller beta functions at Crab Cavities**

    => Previous limits can be increased by factor ~ 5 (~ 0.8 MΩ/m)
  - **Once in collisions in IP1 and IP5, ~ 30 times more Landau damping due to Beam-Beam Head-On (BBHO)**



=> Previous limits can be increased by factor ~ 30 => Could therefore help to collide even earlier if impedance of Crab Cavities cannot be reduced sufficiently

However, this does not work for non-colliding bunches!

HIGH HARMONIC RF SYSTEM (1/3)

- **400 MHz + 800 MHz**

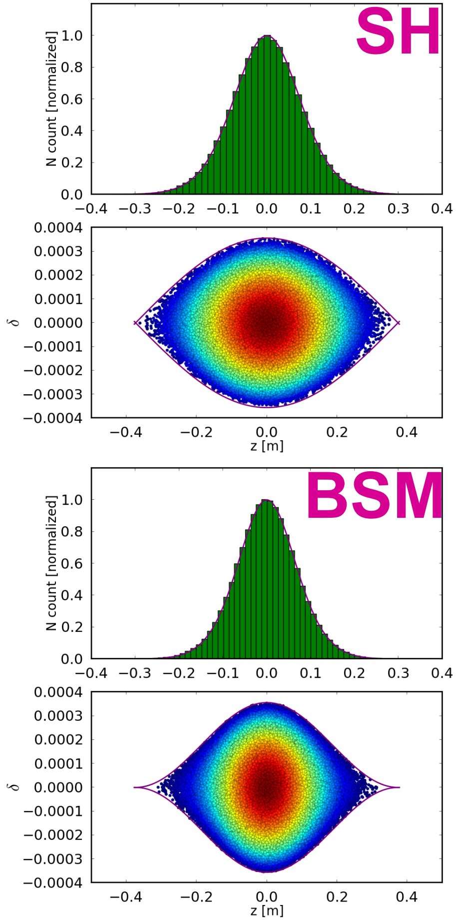
	Single RF	BSM	BLM
V_{400}	16 MV	16 MV	16 MV
V_{800}	0 MV	8 MV	-8 MV
ε_z	2.5 eV s	2.5 eV s	2.5 eV s
Δ_t	1.005 ns	0.926 ns	1.217 ns
ΔE	0.22e-3	0.256e-3	0.172e-3

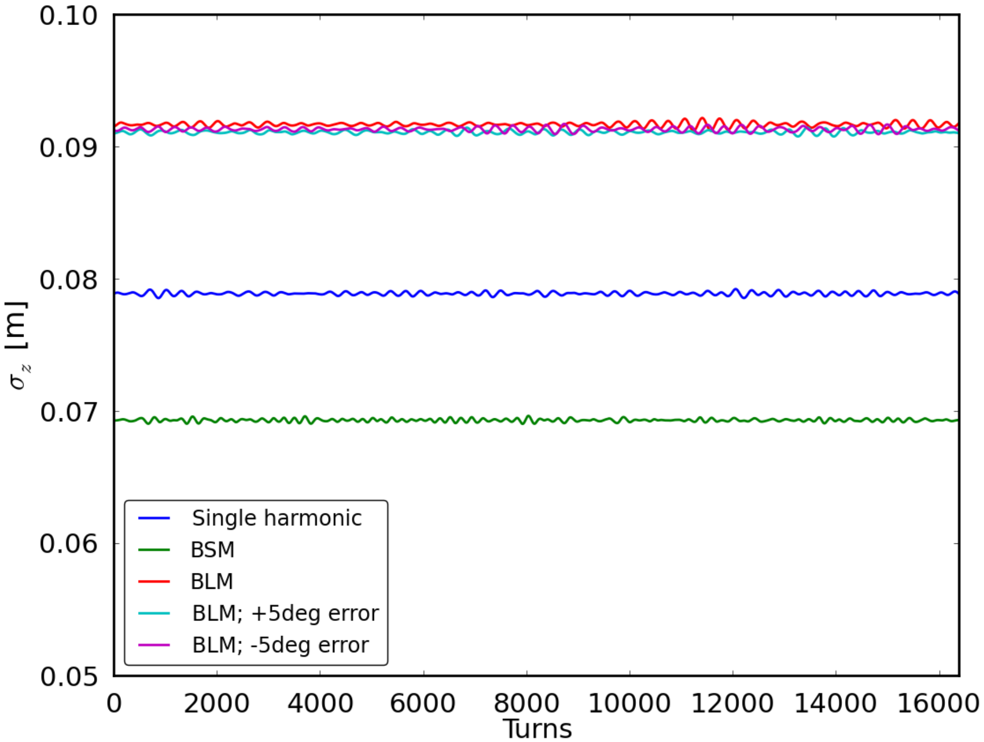
Transverse emittance = 2 μm

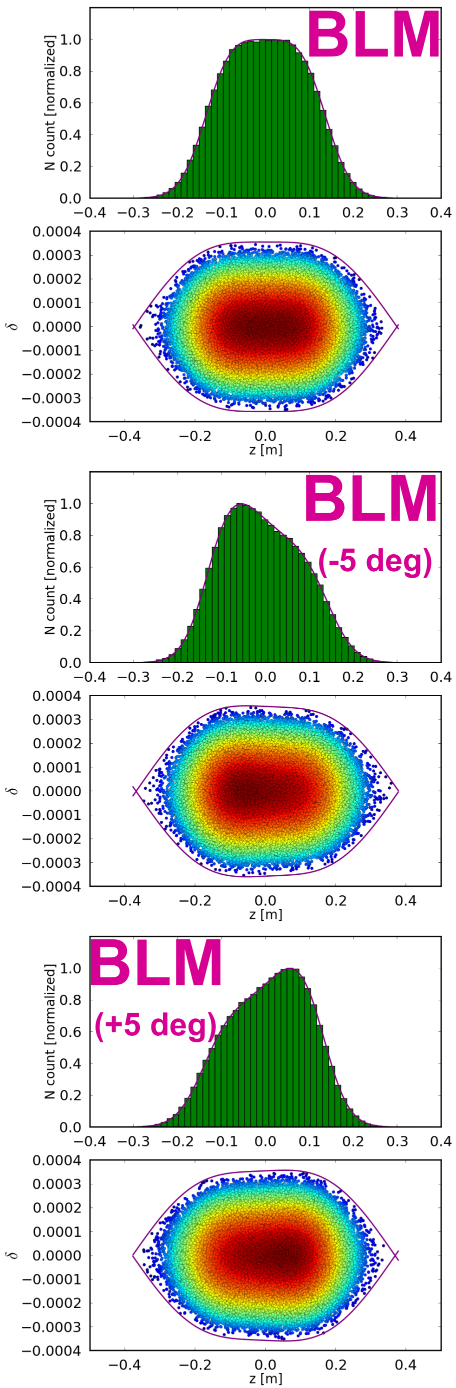
Q'_x	15
Q'_y	15
LOF	+550 A
Dampingrate x	50 turns
Dampingrate y	50 turns

- **Studies made with the baseline impedance model (CFC collimators and no Crab Cavities): single-bunch sim. with HEADTAIL code**

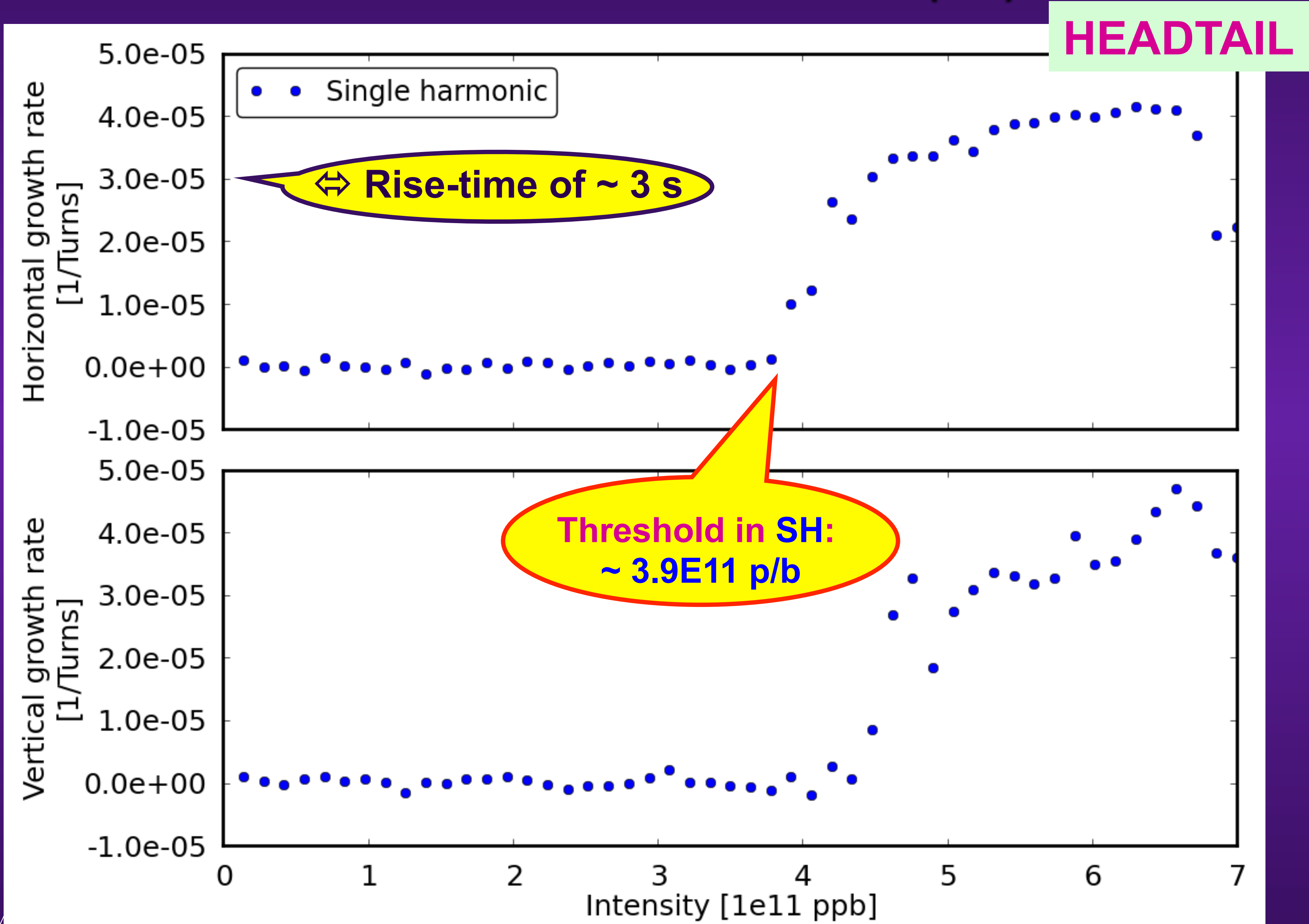
HIGH HARMONIC RF SYSTEM (2/3)



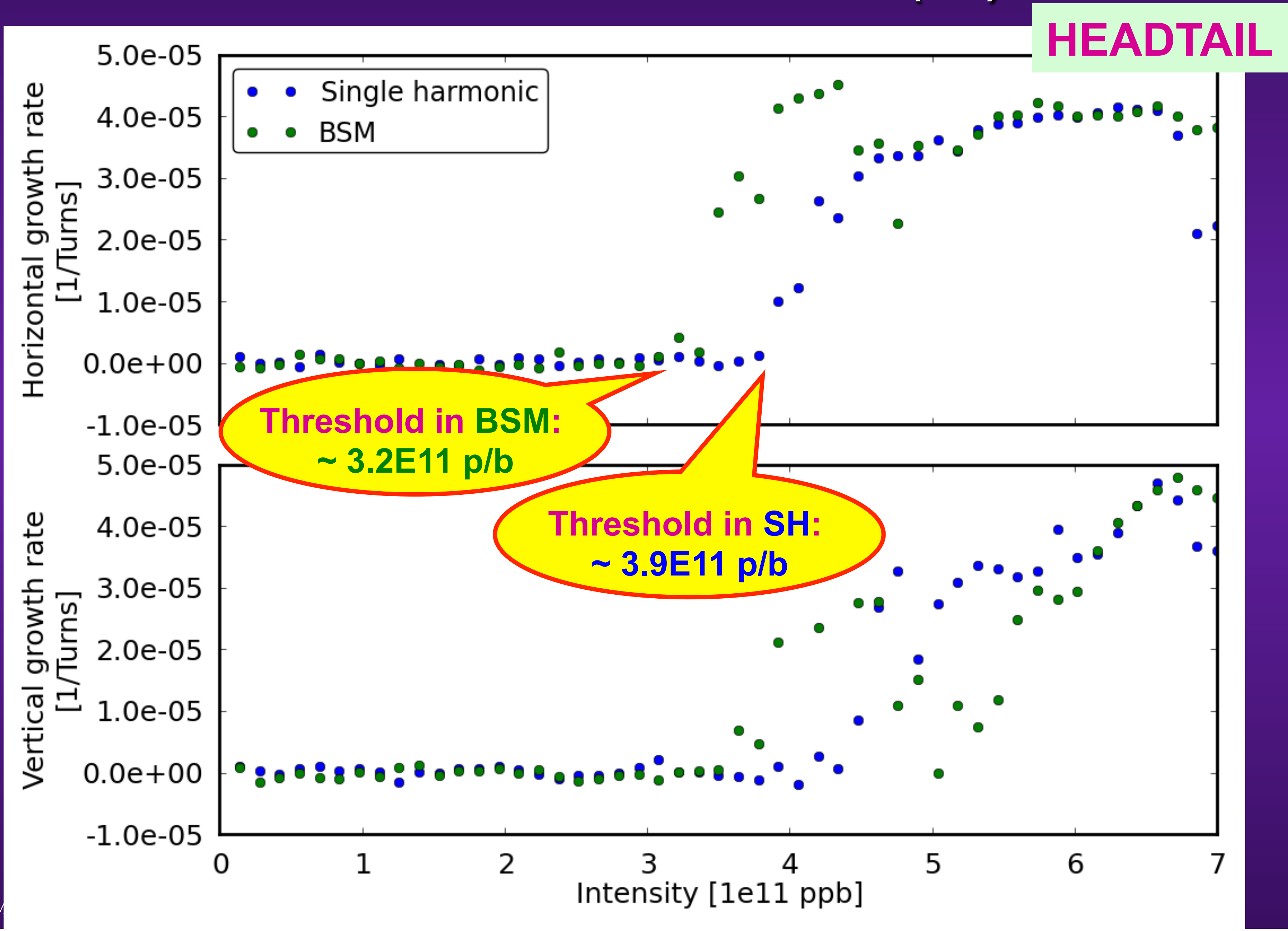




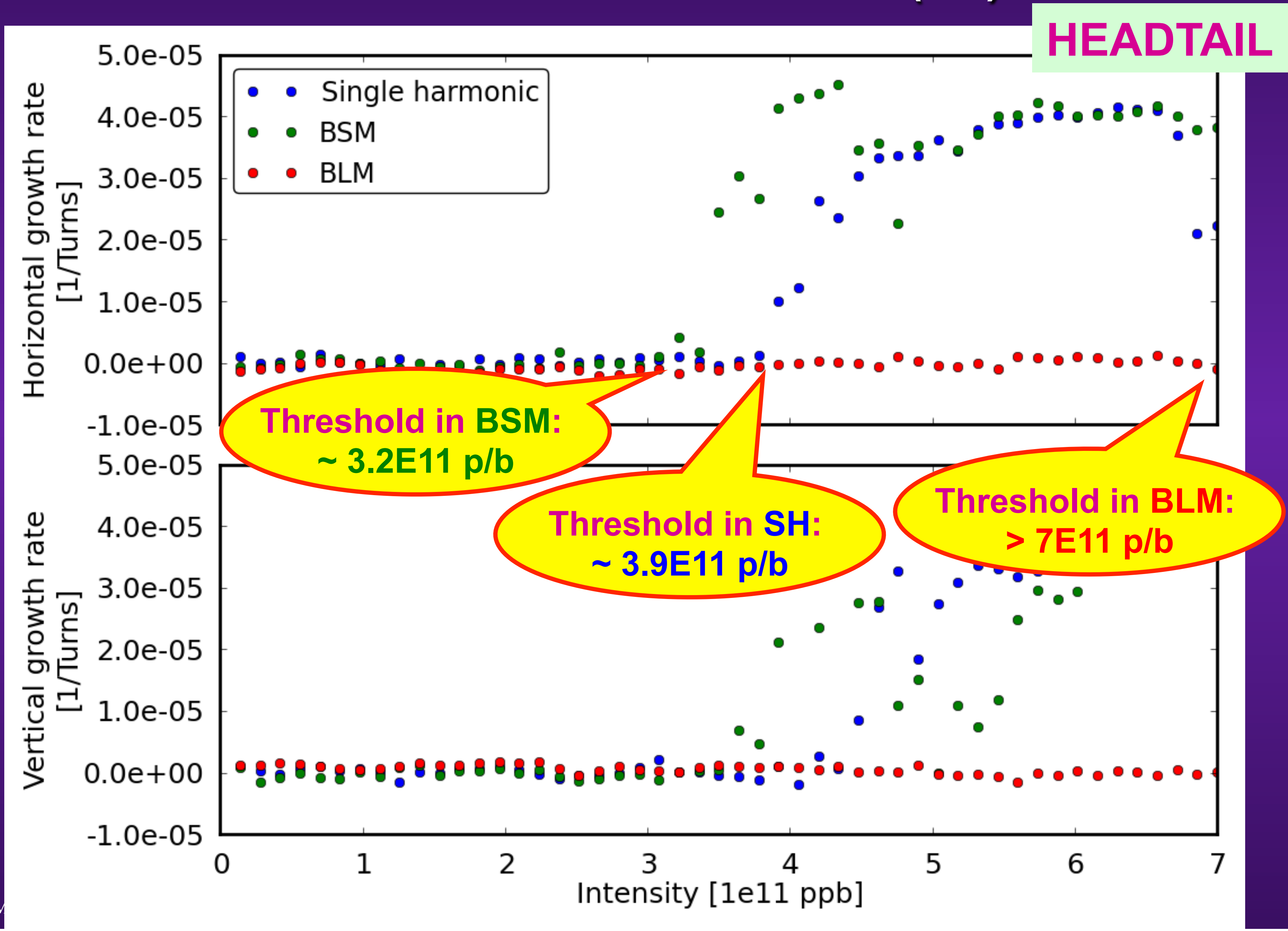
HIGH HARMONIC RF SYSTEM (3/3)



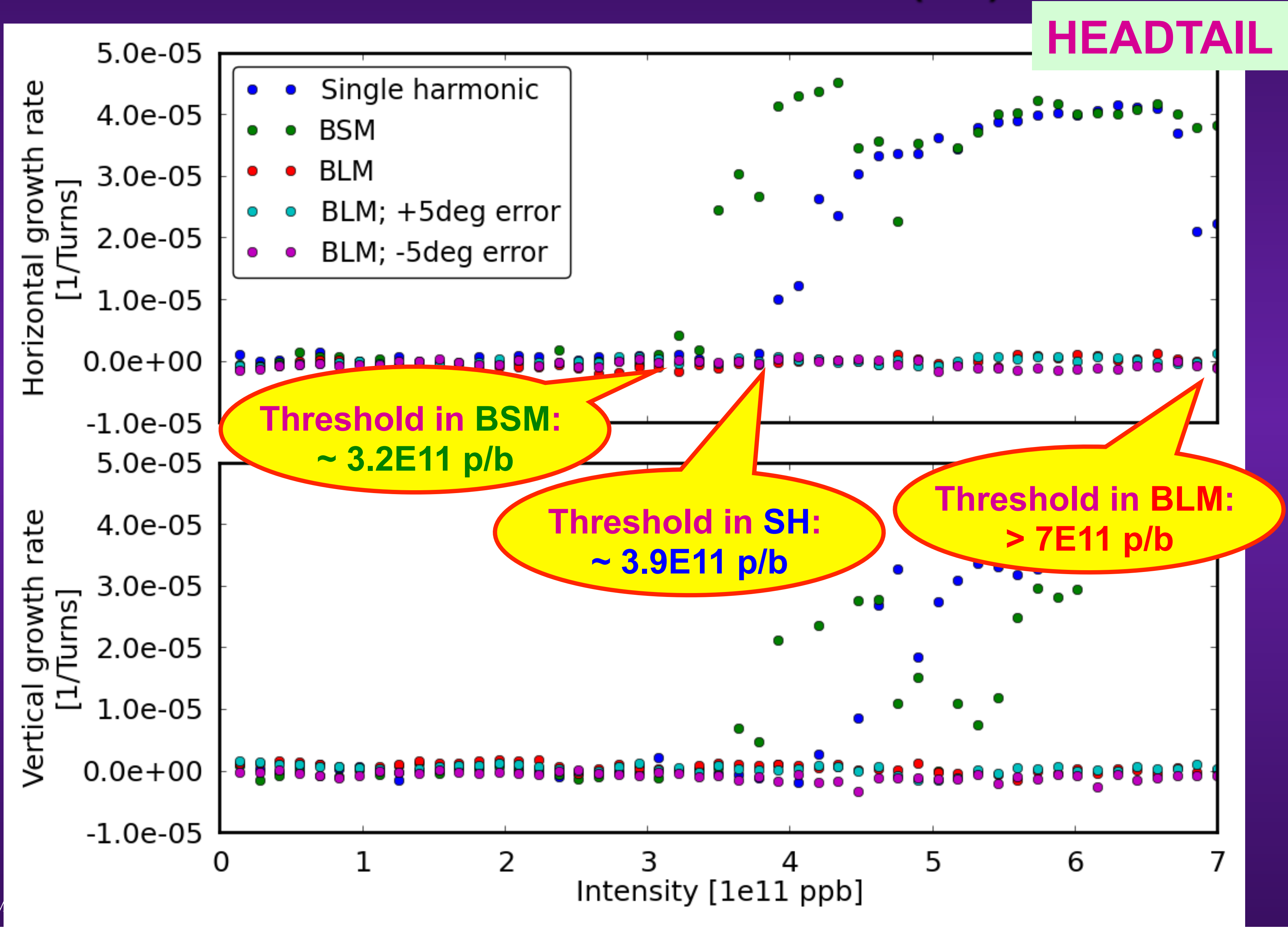
HIGH HARMONIC RF SYSTEM (3/3)



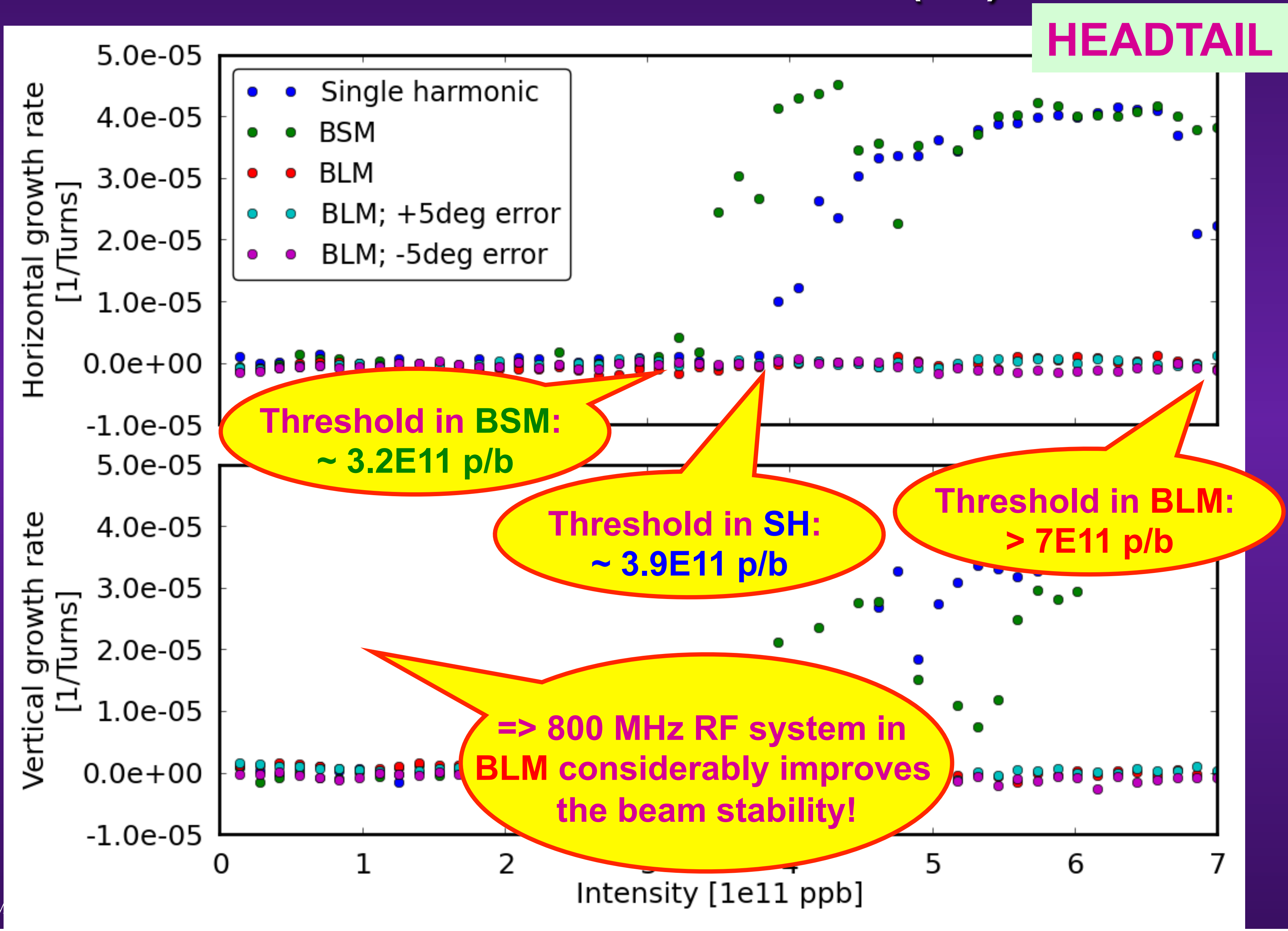
HIGH HARMONIC RF SYSTEM (3/3)



HIGH HARMONIC RF SYSTEM (3/3)



HIGH HARMONIC RF SYSTEM (3/3)



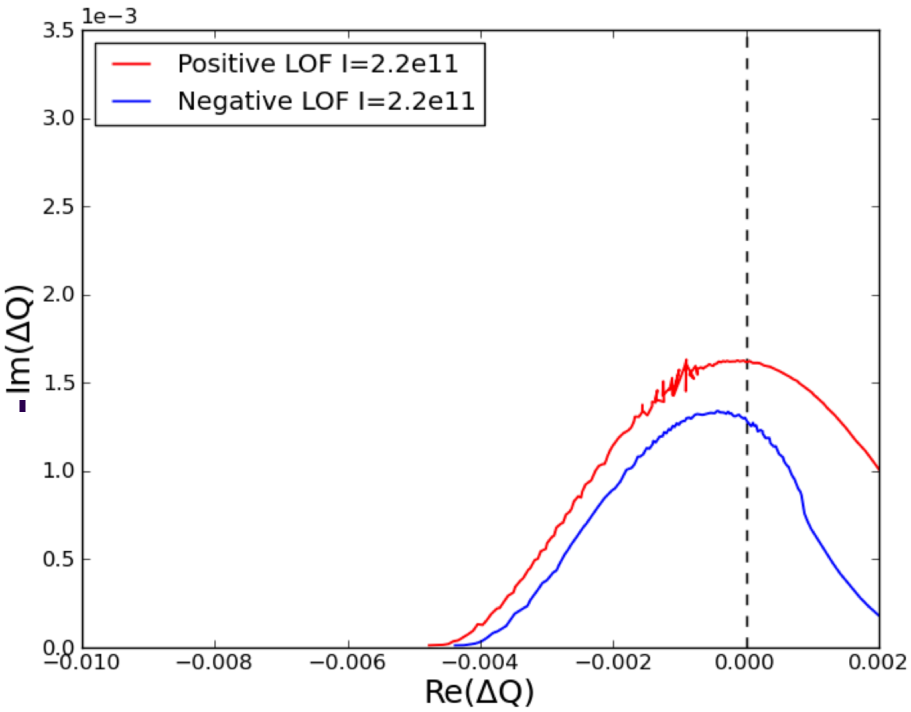
BEAM-BEAM AND OCTUPOLES (1/2)

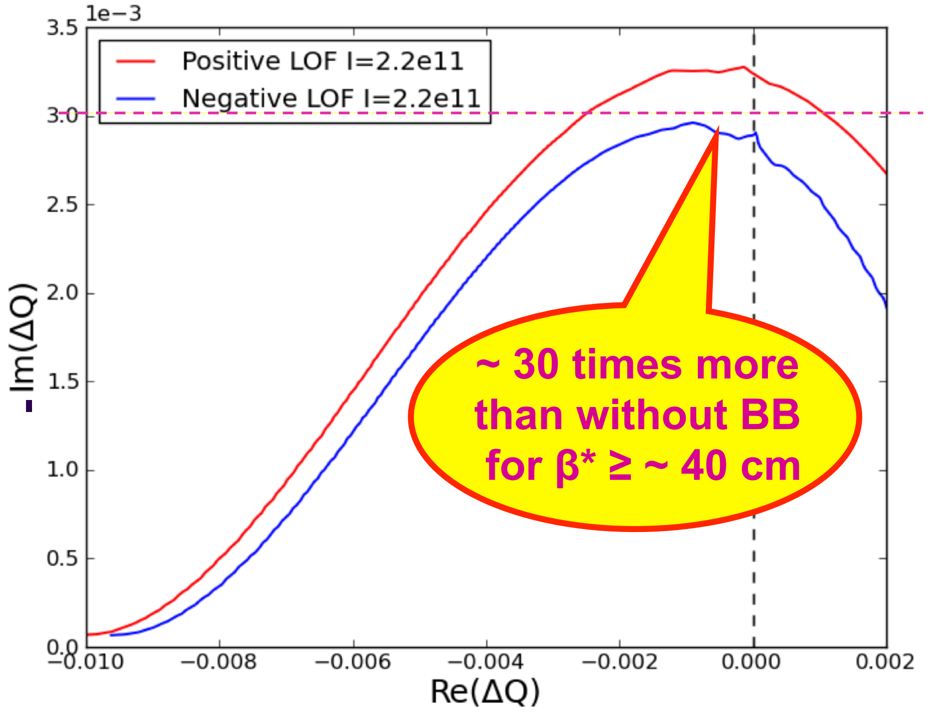
- Collide & Squeeze foreseen at $\beta^* \approx 70$ cm => Better to use LOF > 0 (see TatianaP's talk) but might work also with LOF < 0 (ATS studies)

- What about the interplay between BBHO (Head On) and octupoles?

BEAM-BEAM AND OCTUPOLES (1/2)

- Collide & Squeeze foreseen at β* ≈ 70 cm => Better to use LOF > 0 (see TatianaP's talk) but might work also with LOF < 0 (ATS studies)
- What about the interplay between BBHO (Head On) and octupoles?

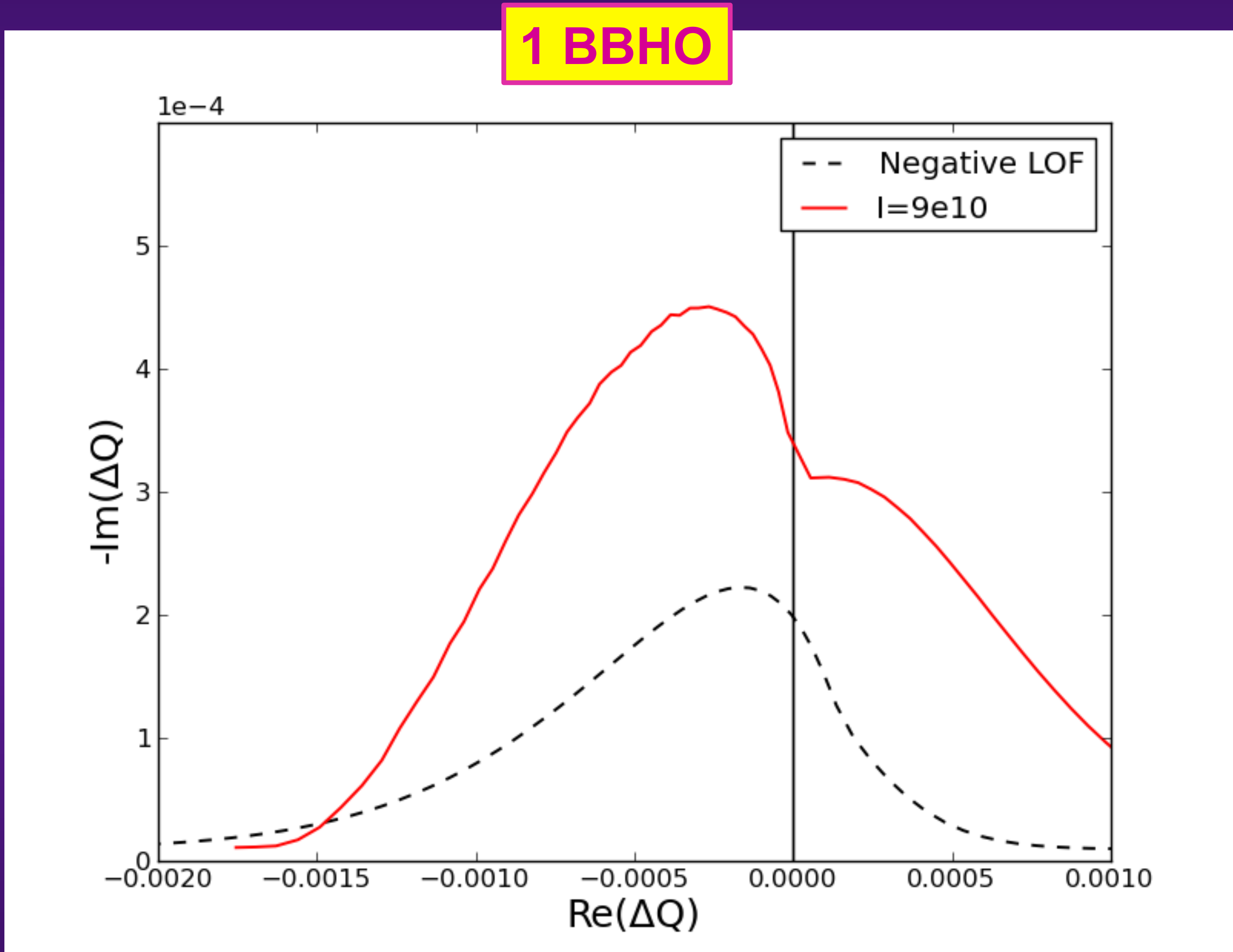




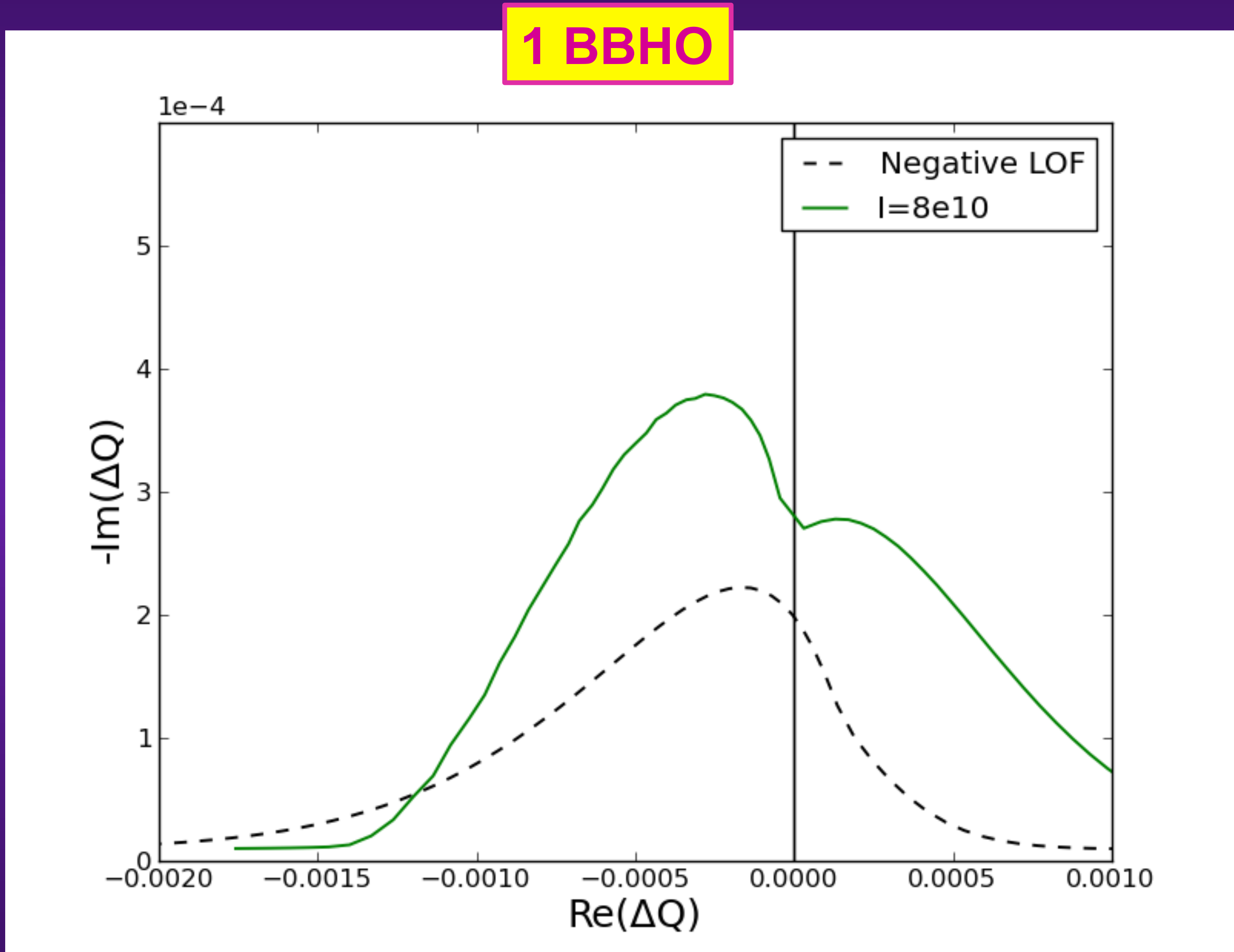
1 BBHO (2.2E11 p/b, 2.5 μm)

2 BBHO (2.2E11 p/b, 2.5 μm)

BEAM-BEAM AND OCTUPOLES (2/2)

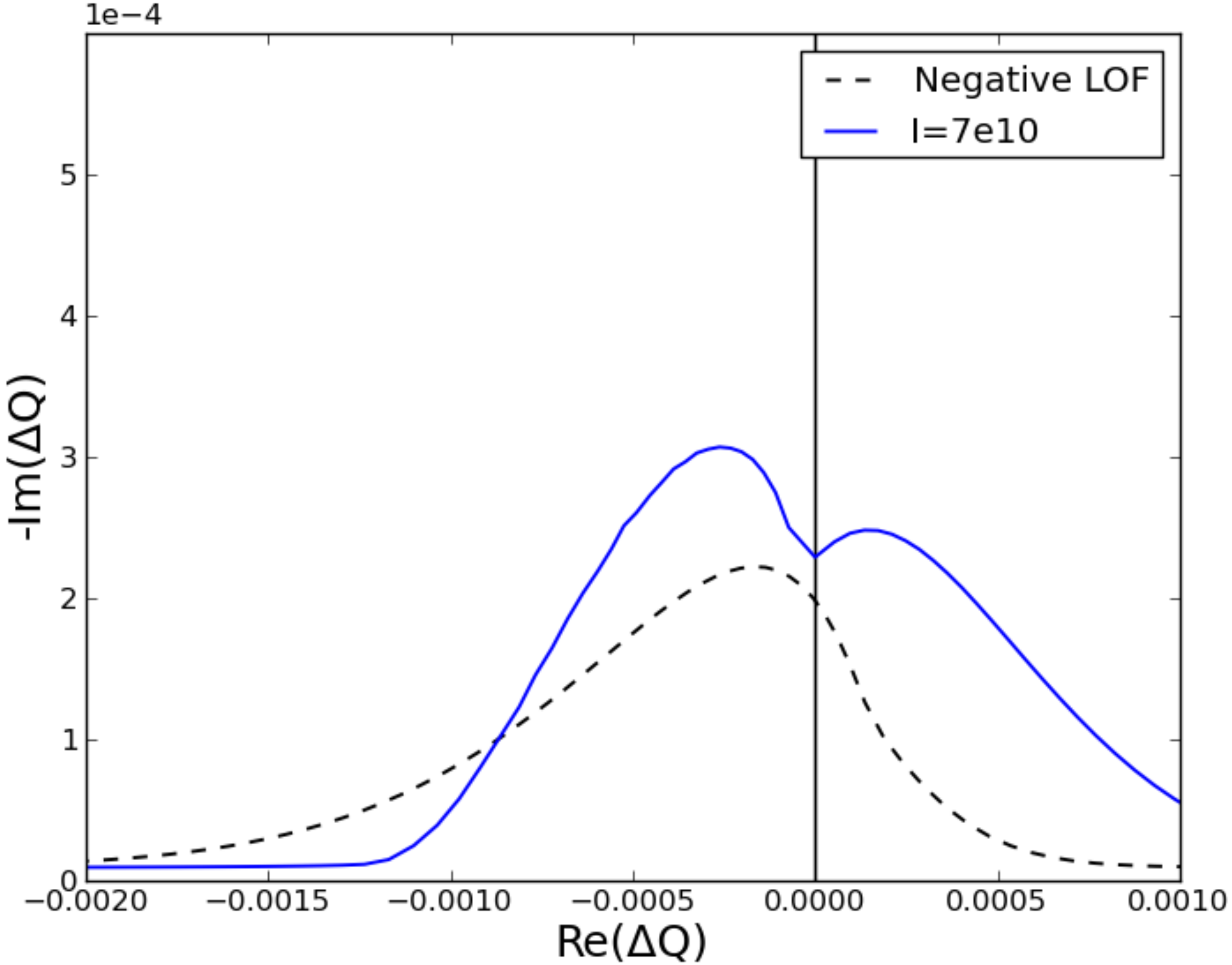


BEAM-BEAM AND OCTUPOLES (2/2)



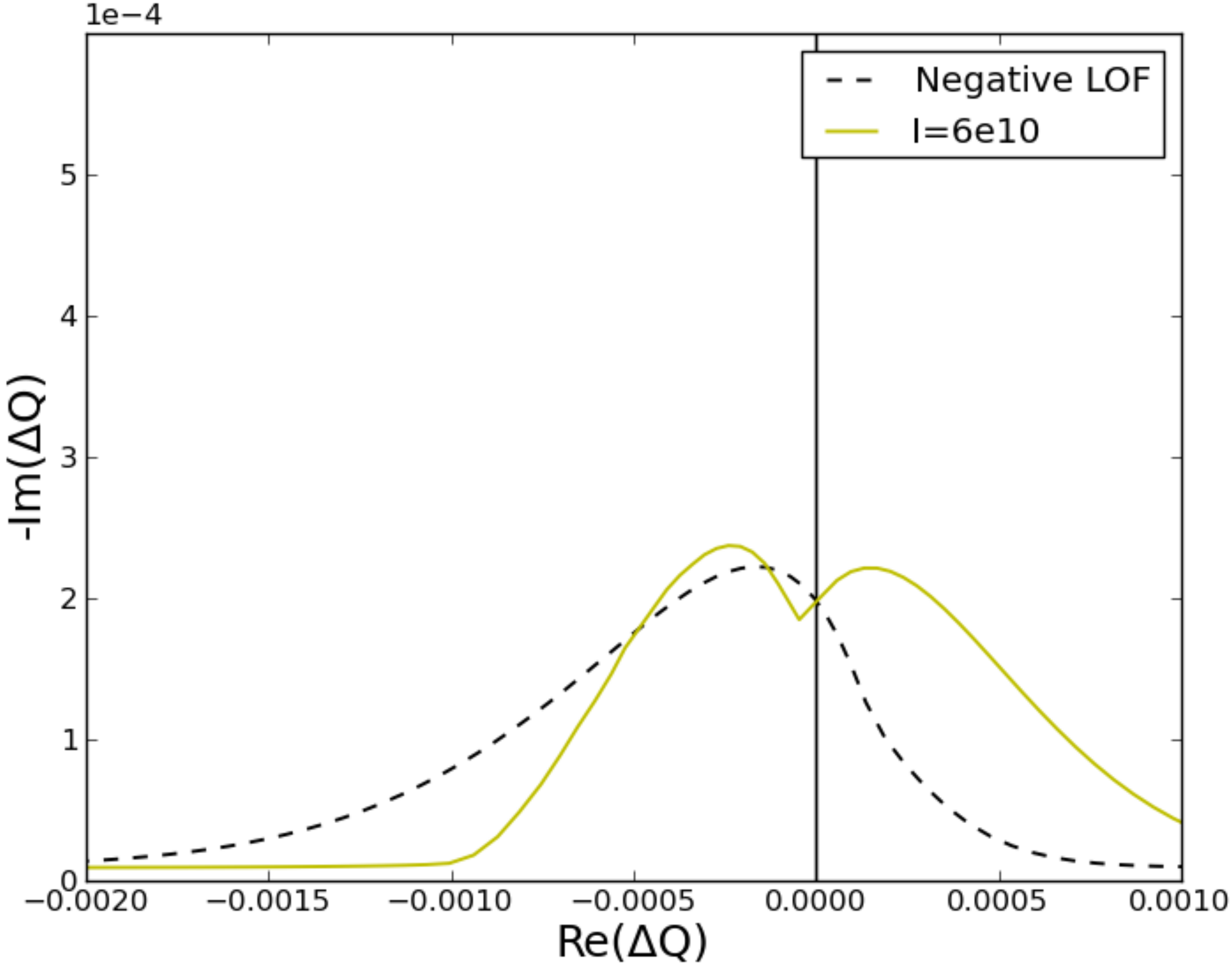
BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO



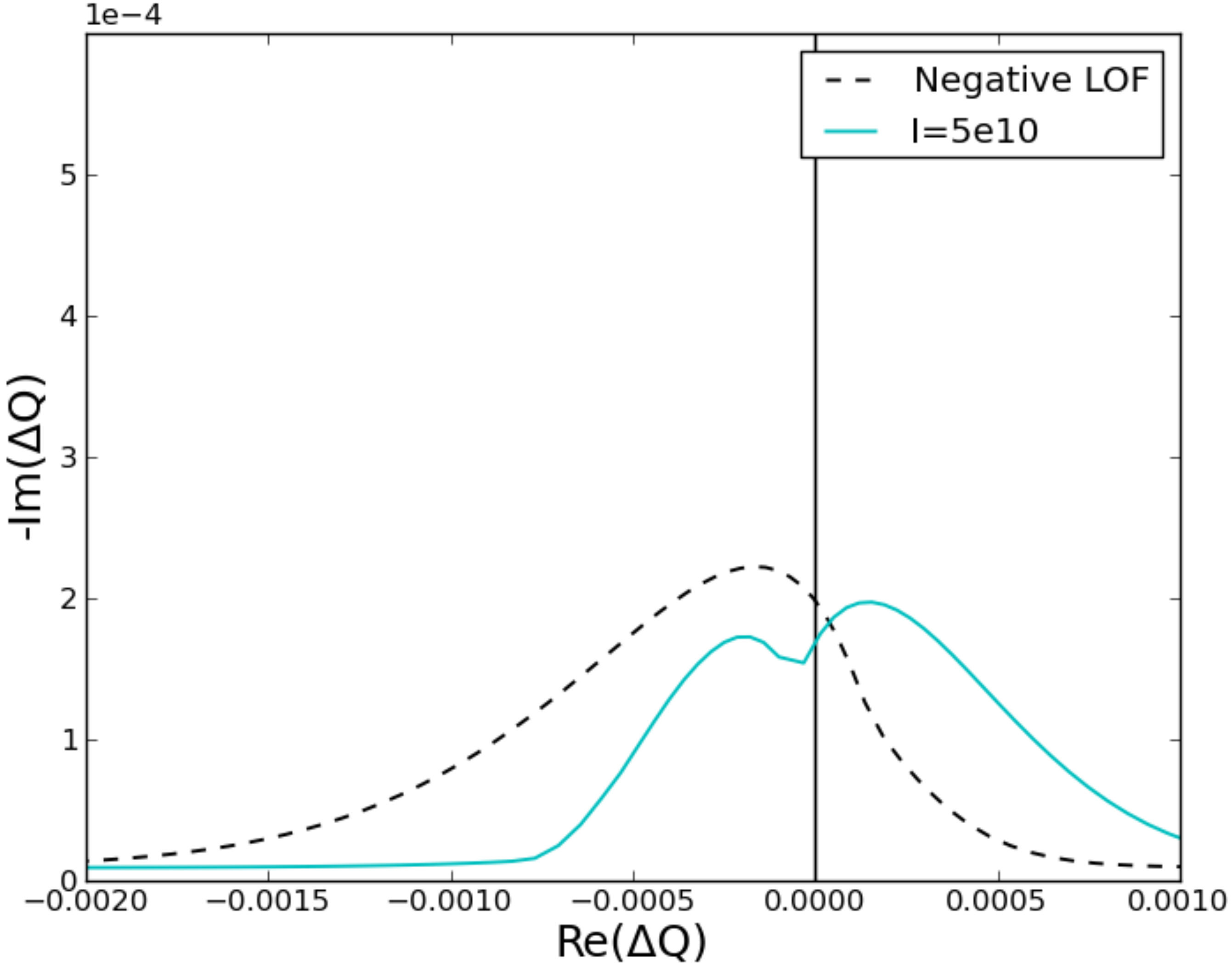
BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO



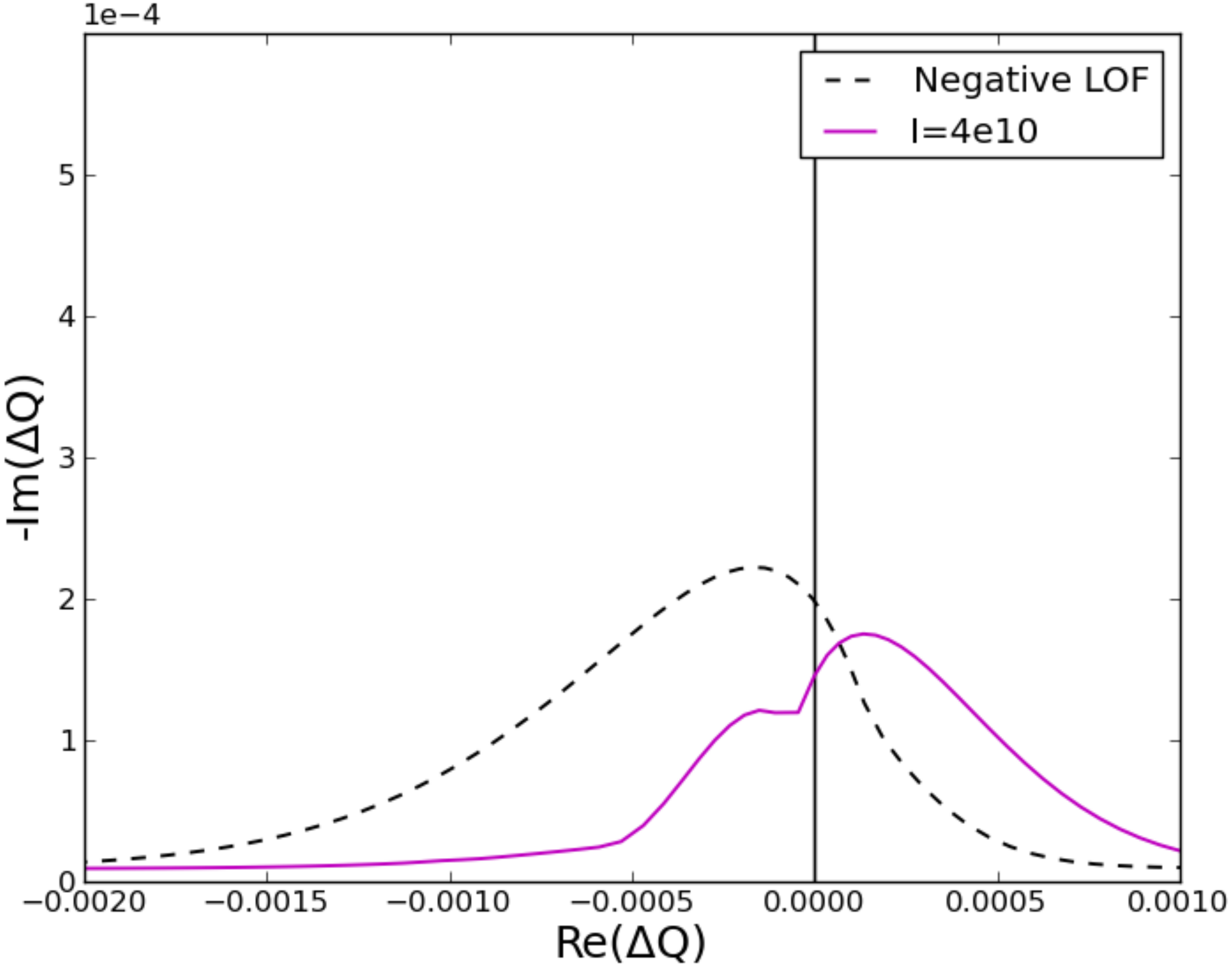
BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO

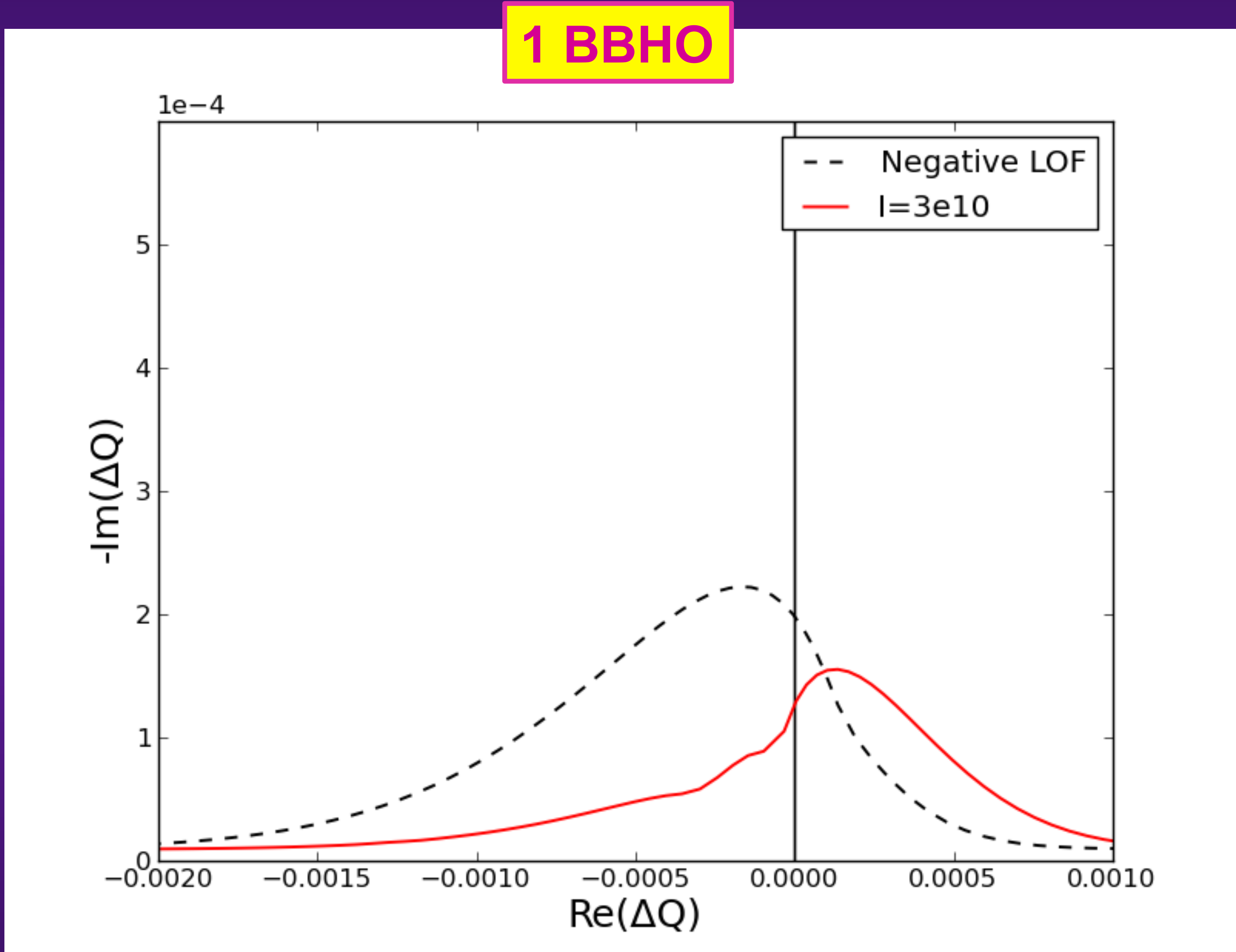


BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO

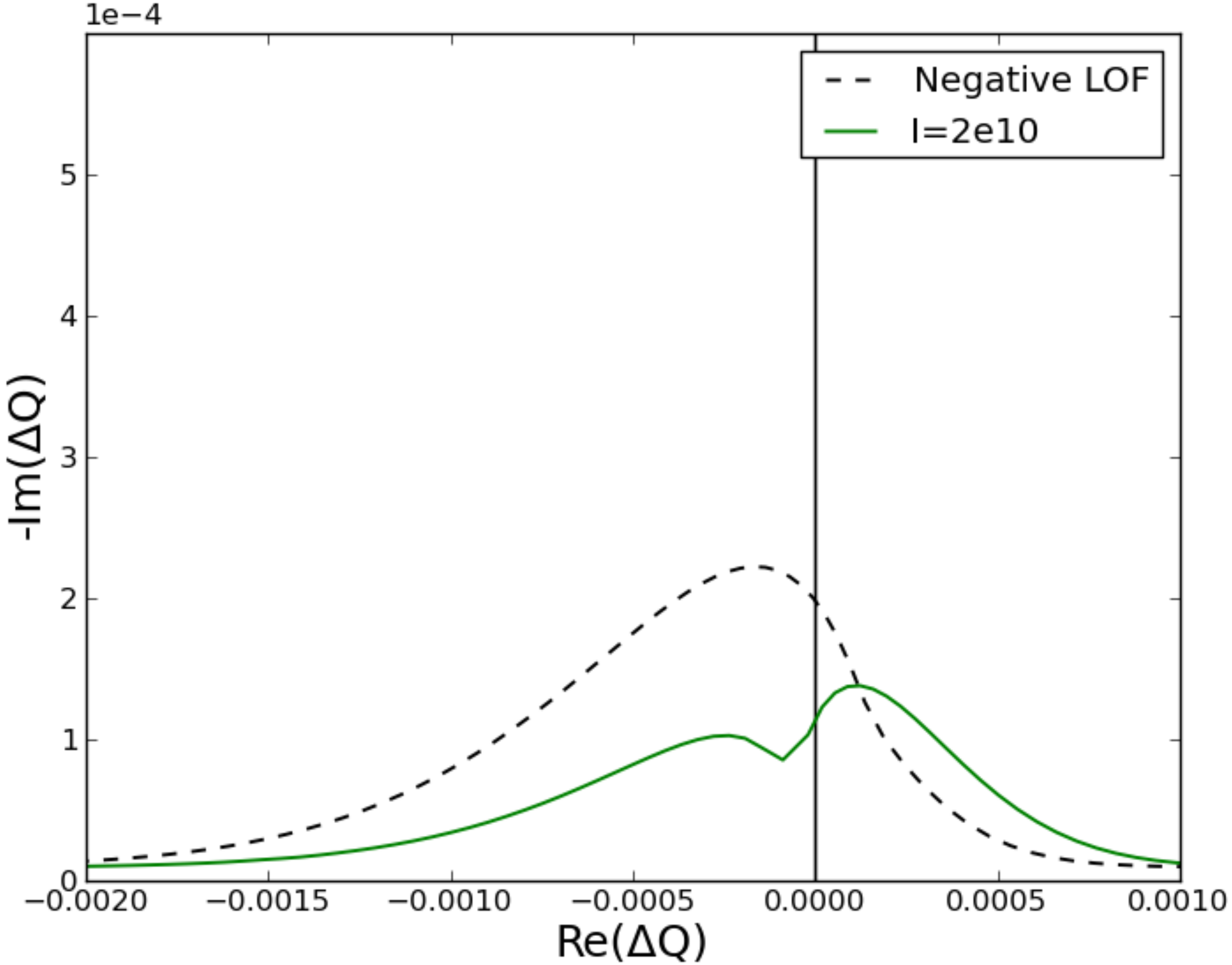


BEAM-BEAM AND OCTUPOLES (2/2)



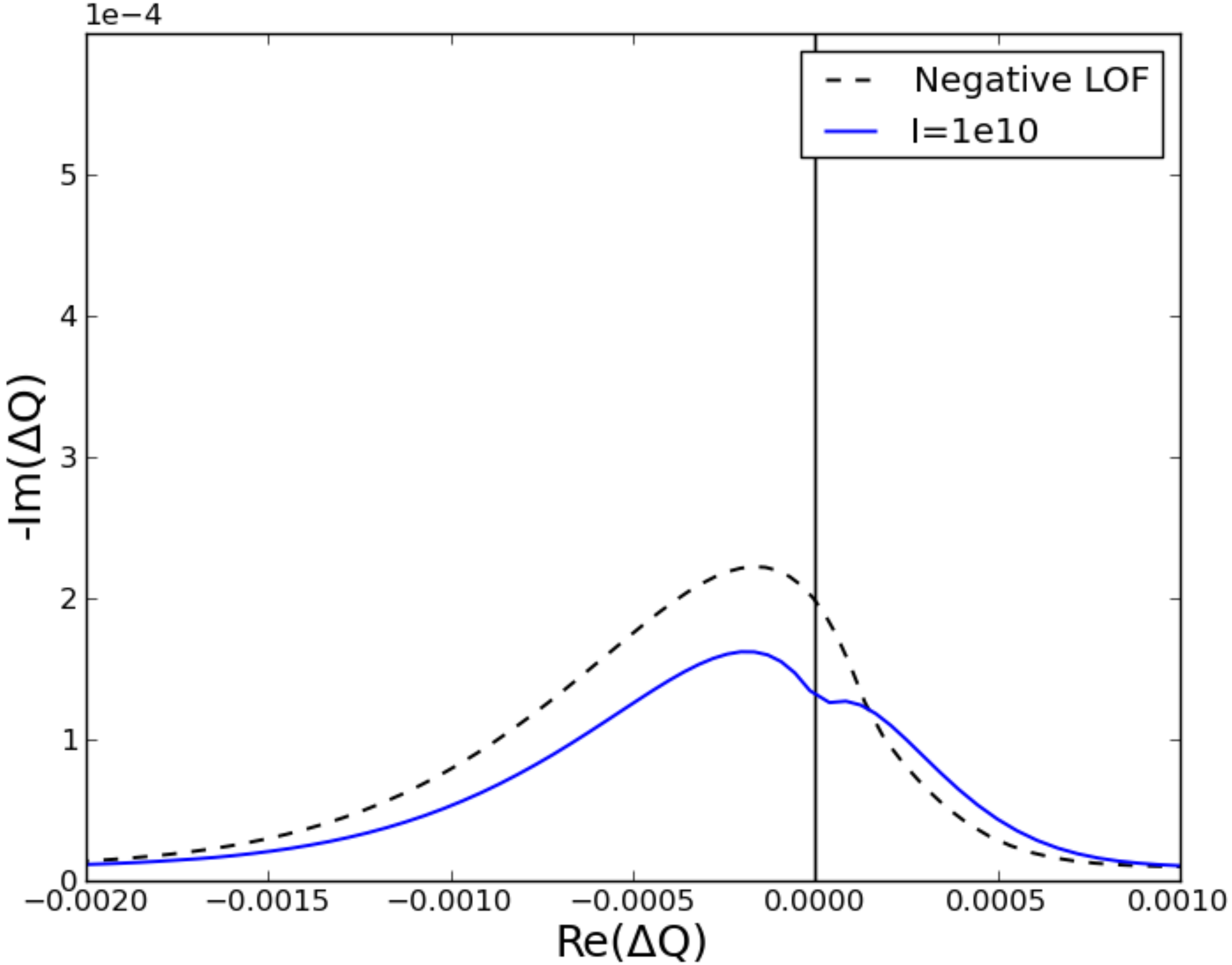
BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO



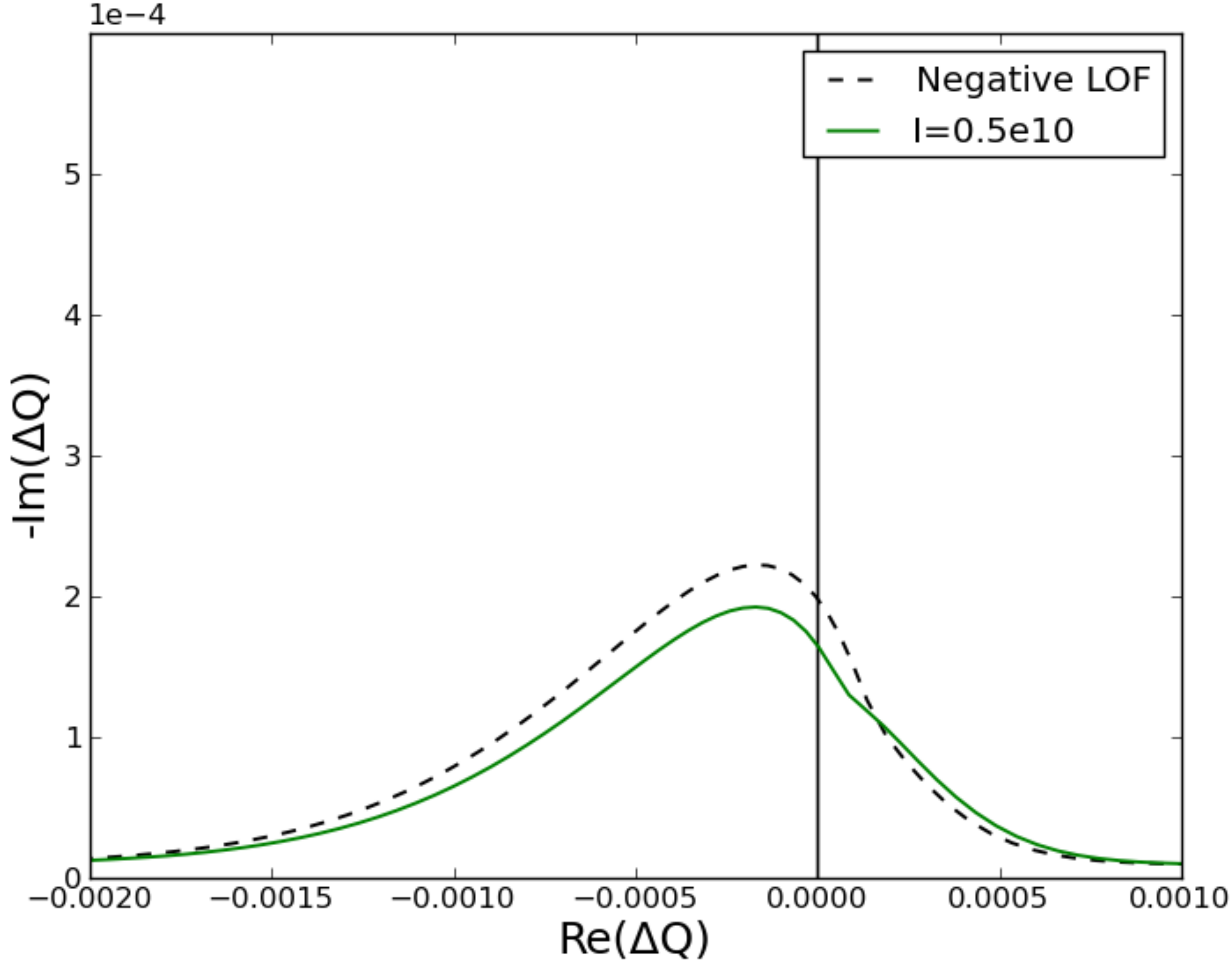
BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO

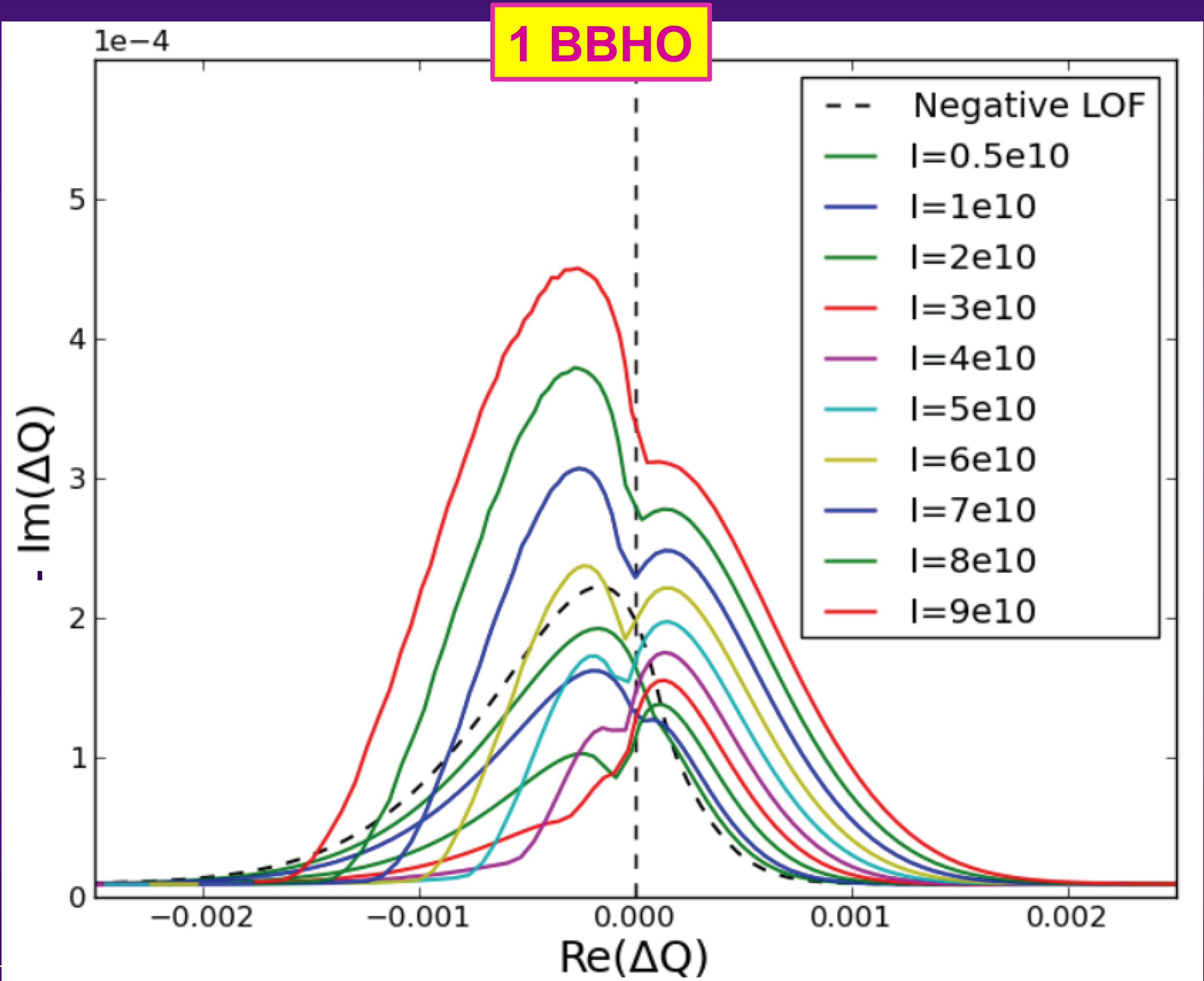


BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO



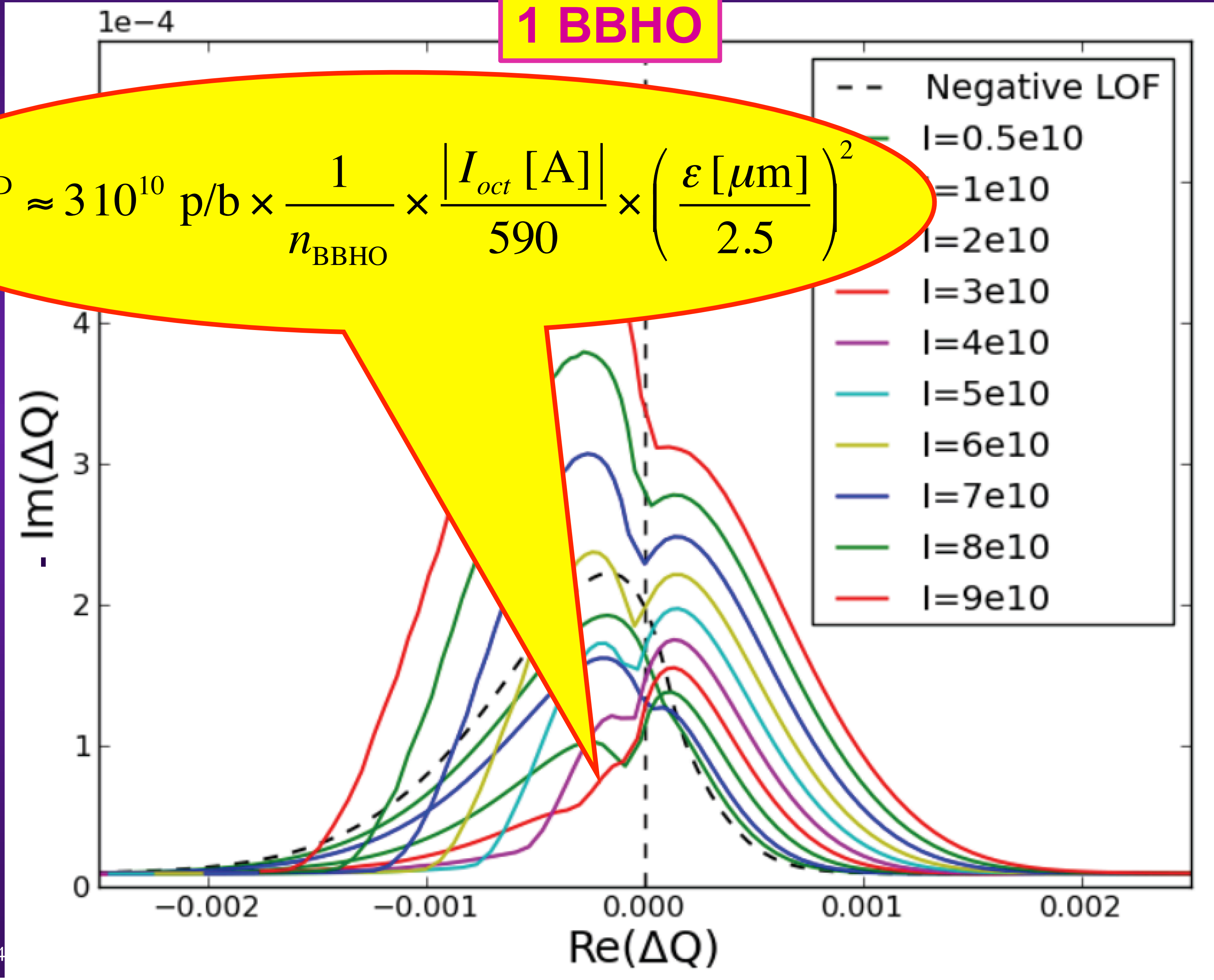
BEAM-BEAM AND OCTUPOLES (2/2)



BEAM-BEAM AND OCTUPOLES (2/2)

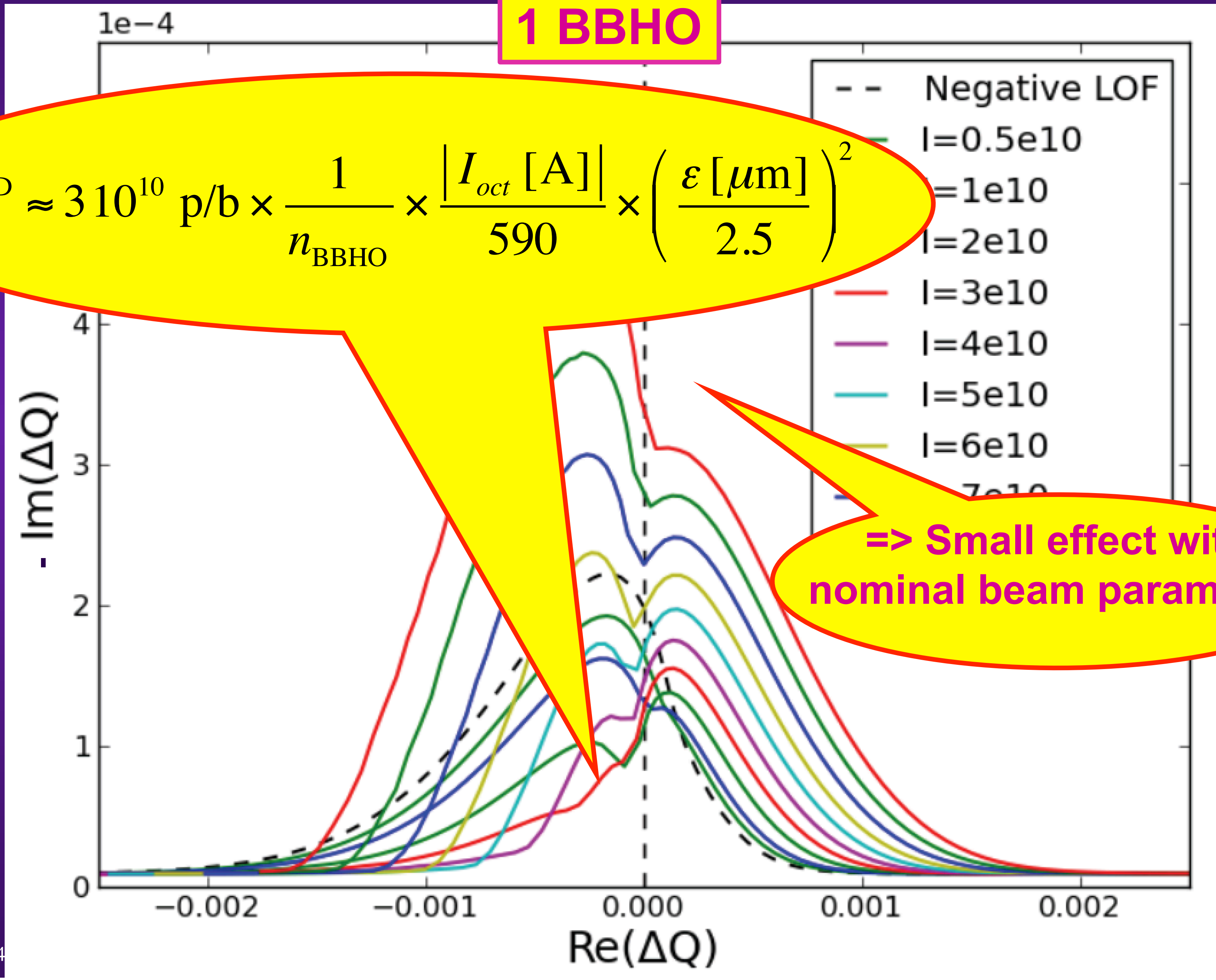
1 BBHO

$$N_b^{\text{min SD}} \approx 3\,10^{10}\ \text{p/b} \times \frac{1}{n_{\text{BBHO}}} \times \frac{\left|I_{oct}\,[\text{A}]\right|}{590} \times \left(\frac{\varepsilon\,[\mu\text{m}]}{2.5}\right)^2$$



BEAM-BEAM AND OCTUPOLES (2/2)

1 BBHO



$$N_b^{\min \mathrm{SD}} \approx 3\,10^{10}\ \mathrm{p/b} \times \frac{1}{n_{\mathrm{BBHO}}} \times \frac{\left| I_{oct}\,[\mathrm{A}] \right|}{590} \times \left(\frac{\varepsilon\,[\mu \mathrm{m}]}{2.5} \right)^2$$

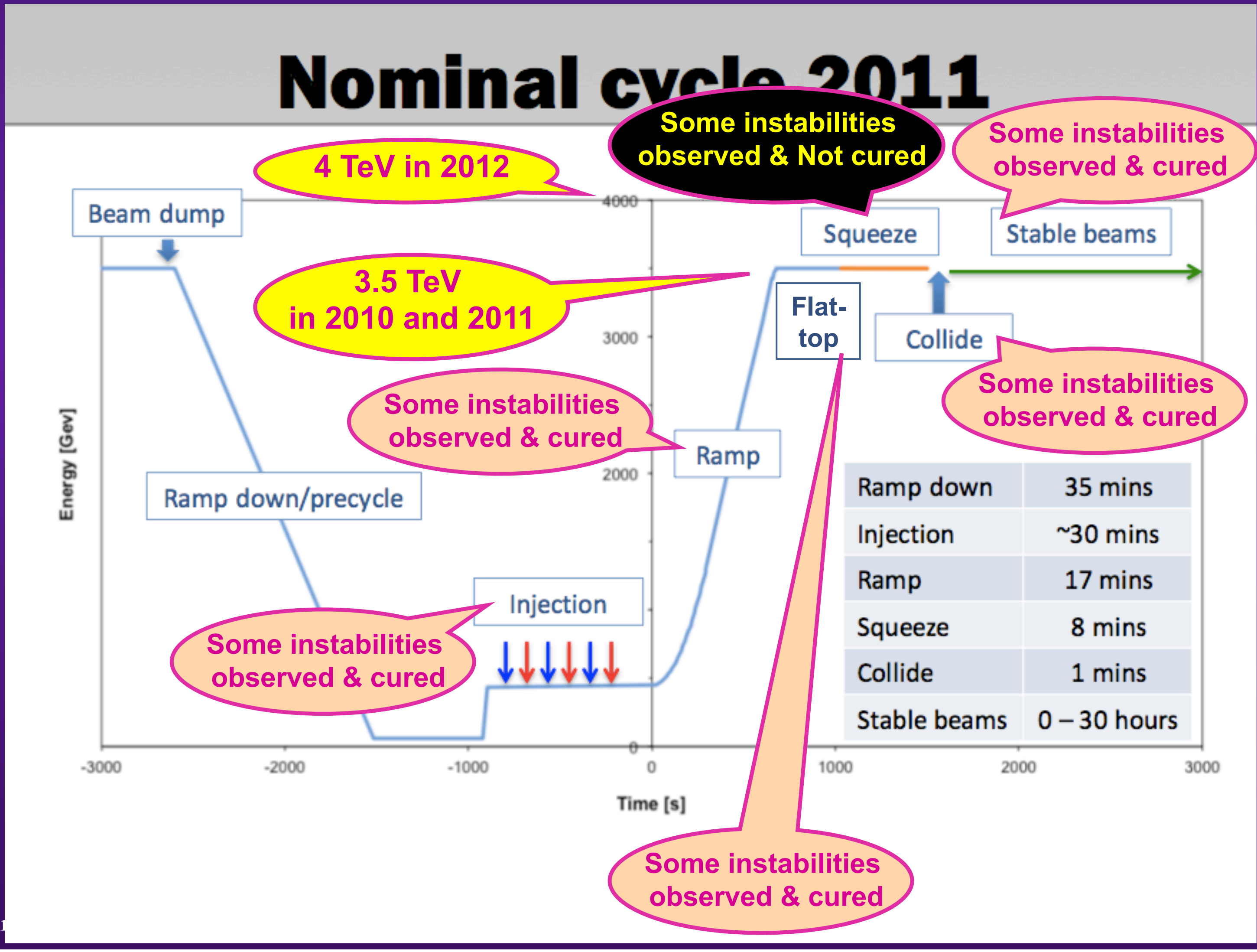
=> Small effect with nominal beam parameters

CONCLUSIONS (1/4)

- Transverse instabilities are a concern based on the experience of the LHC Run I

CONCLUSIONS (1/4)

- Transverse instabilities are a concern based on the experience of the LHC Run I



CONCLUSIONS (2/4)

- **To reach single-beam transverse stability, it is necessary to**

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)

CONCLUSIONS (2/4)

- **To reach single-beam transverse stability, it is necessary to**
  - **Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)**
  - **Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk**

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)
  - Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk
- Single-beam stability also relies on the transverse damper (~ 50 turns), high chromaticity (from 2012 => Q' ≈ + 15, BUT still needs to be optimized) and Landau octupoles (LOF = + 590 A @ 7 TeV)

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)
  - Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk
- Single-beam stability also relies on the transverse damper (~ 50 turns), high chromaticity (from 2012 => Q' ≈ + 15, BUT still needs to be optimized) and Landau octupoles (LOF = + 590 A @ 7 TeV)
- For luminosity leveling reason => β* leveling: Collide (at β* ≈ 70 cm) & Squeeze (down to 15 cm)

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)
  - Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk
- Single-beam stability also relies on the transverse damper (~ 50 turns), high chromaticity (from 2012 => Q' ≈ + 15, BUT still needs to be optimized) and Landau octupoles (LOF = + 590 A @ 7 TeV)
- For luminosity leveling reason => β* leveling: Collide (at β* ≈ 70 cm) & Squeeze (down to 15 cm)
- If issue with single-beam stability before the squeeze

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)
  - Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk
- Single-beam stability also relies on the transverse damper (~ 50 turns), high chromaticity (from 2012 => Q' ≈ + 15, BUT still needs to be optimized) and Landau octupoles (LOF = + 590 A @ 7 TeV)
- For luminosity leveling reason => β* leveling: Collide (at β* ≈ 70 cm) & Squeeze (down to 15 cm)
- If issue with single-beam stability before the squeeze
  - LOF = - 590 A + Collide & Squeeze (at the needed β*…)

CONCLUSIONS (2/4)

- To reach single-beam transverse stability, it is necessary to
  - Coat the collimators with 5 μm of Molybdenum (or, to coat new Molybdenum-Graphite collimators)
  - Still decrease the impedance of the Crab Cavities (both R and R/Q) => See latest HOMs list in N. Biancacci's talk
- Single-beam stability also relies on the transverse damper (~ 50 turns), high chromaticity (from 2012 => Q' ≈ + 15, BUT still needs to be optimized) and Landau octupoles (LOF = + 590 A @ 7 TeV)
- For luminosity leveling reason => β* leveling: Collide (at β* ≈ 70 cm) & Squeeze (down to 15 cm)
- If issue with single-beam stability before the squeeze
  - LOF = - 590 A + Collide & Squeeze (at the needed β*…)
  - If not enough => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**
  - **Collide & Squeeze (at the needed β*…)**

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**
  - **Collide & Squeeze (at the needed β*…)**
  - **If not possible => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?**

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**
  - **Collide & Squeeze (at the needed β*…)**
  - **If not possible => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?**
- **What about non-colliding bunches required by the experiments?**

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**
  - **Collide & Squeeze (at the needed β*…)**
  - **If not possible => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?**
- **What about non-colliding bunches required by the experiments?**
  - **Might be lost if collision is required for beam/bunch stability**

CONCLUSIONS (3/4)

- **If issue with single-beam stability during the squeeze**
  - **Collide & Squeeze (at the needed β*…)**
  - **If not possible => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?**
- **What about non-colliding bunches required by the experiments?**
  - **Might be lost if collision is required for beam/bunch stability**
  - **Might prevent from reducing chromaticity (and octupoles) once in collision (much better for lifetime)**

CONCLUSIONS (3/4)

- If issue with single-beam stability during the squeeze
  - Collide & Squeeze (at the needed β*…)
  - If not possible => Add more Landau damping, using e.g. new RFQs (A. Grudiev). What about impedance?
- What about non-colliding bunches required by the experiments?
  - Might be lost if collision is required for beam/bunch stability
  - Might prevent from reducing chromaticity (and octupoles) once in collision (much better for lifetime)
- An additional 800 MHz RF system operating in BLM would considerably increase the intensity threshold (with Q' = 15, octupole current LOF = + 550 A and damper @ 50 turns) => BLM still stable at bunch intensity 80% higher than intensity threshold with single RF (higher intensities still to be studied). What about impedance?

CONCLUSIONS (4/4)

- The beam stability in the presence of electron cloud in the quadrupoles still needs to be assessed

CONCLUSIONS (4/4)

- The beam stability in the presence of electron cloud in the quadrupoles still needs to be assessed

- Finally, the transverse instability at injection should be studied in the presence of space charge

CONCLUSIONS (4/4)

- The beam stability in the presence of electron cloud in the quadrupoles still needs to be assessed

- Finally, the transverse instability at injection should be studied in the presence of space charge

    - Some octupoles (with a current of 6.5 A) were needed at injection during Run I to prevent some instabilities from developing on some injected batches

CONCLUSIONS (4/4)

- The beam stability in the presence of electron cloud in the quadrupoles still needs to be assessed

- Finally, the transverse instability at injection should be studied in the presence of space charge

  - Some octupoles (with a current of 6.5 A) were needed at injection during Run I to prevent some instabilities from developing on some injected batches

  - This instability still remains to be understood in detail

CONCLUSIONS (4/4)

- The beam stability in the presence of electron cloud in the quadrupoles still needs to be assessed

- Finally, the transverse instability at injection should be studied in the presence of space charge

  - Some octupoles (with a current of 6.5 A) were needed at injection during Run I to prevent some instabilities from developing on some injected batches

  - This instability still remains to be understood in detail

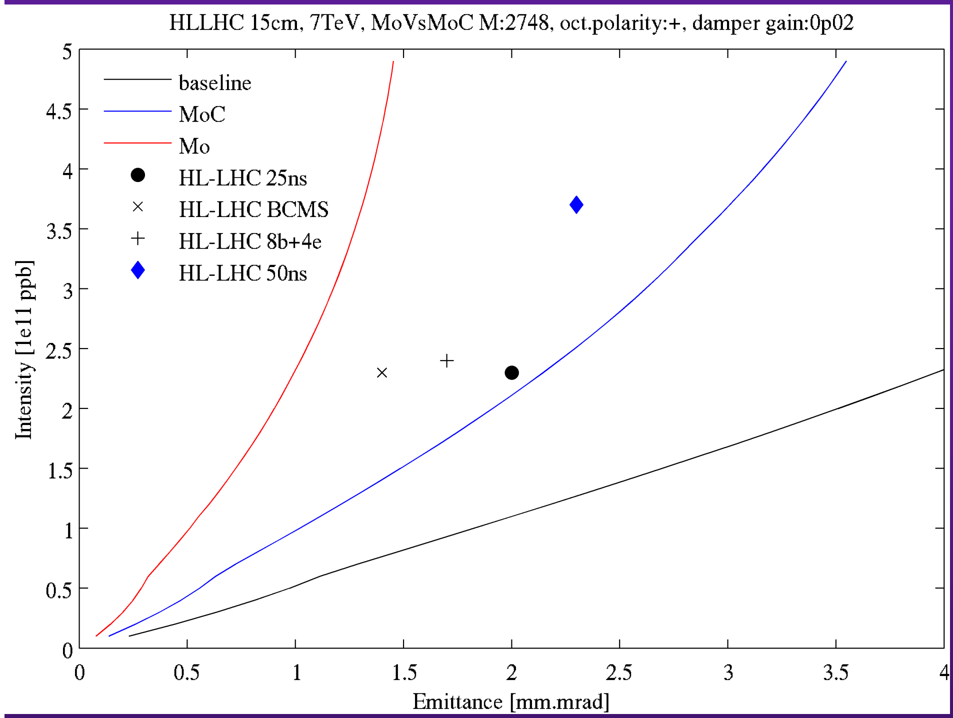
  - Furthermore, the value of the octupole current was never optimized and it might be a problem in the future, for dynamic aperture considerations, if the octupole current needs to be increased

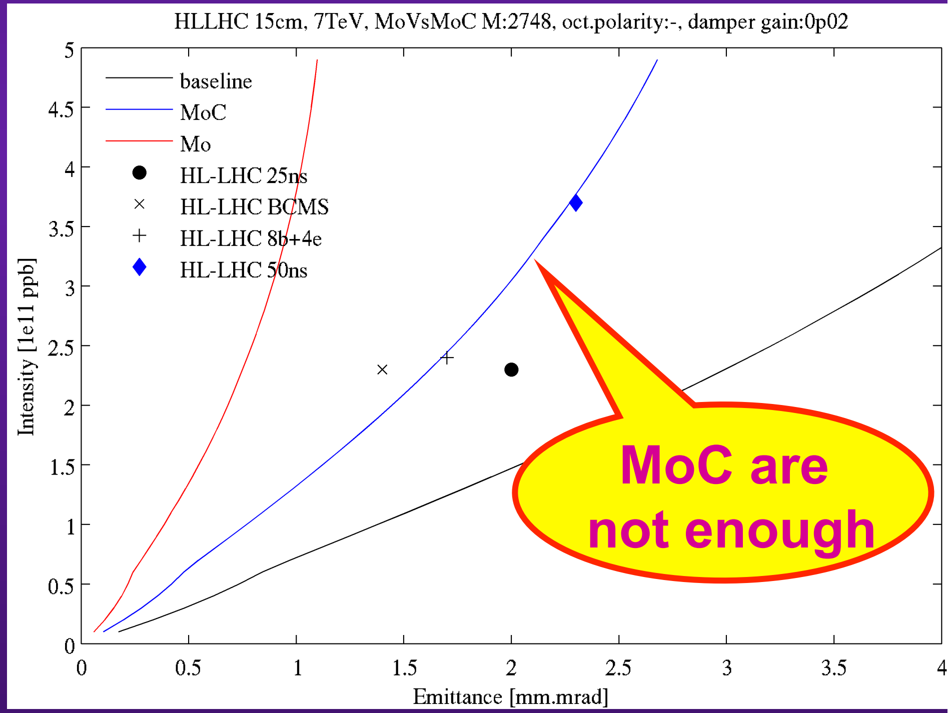
APPENDIX

Octupole polarity: LOF > 0

LOF < 0

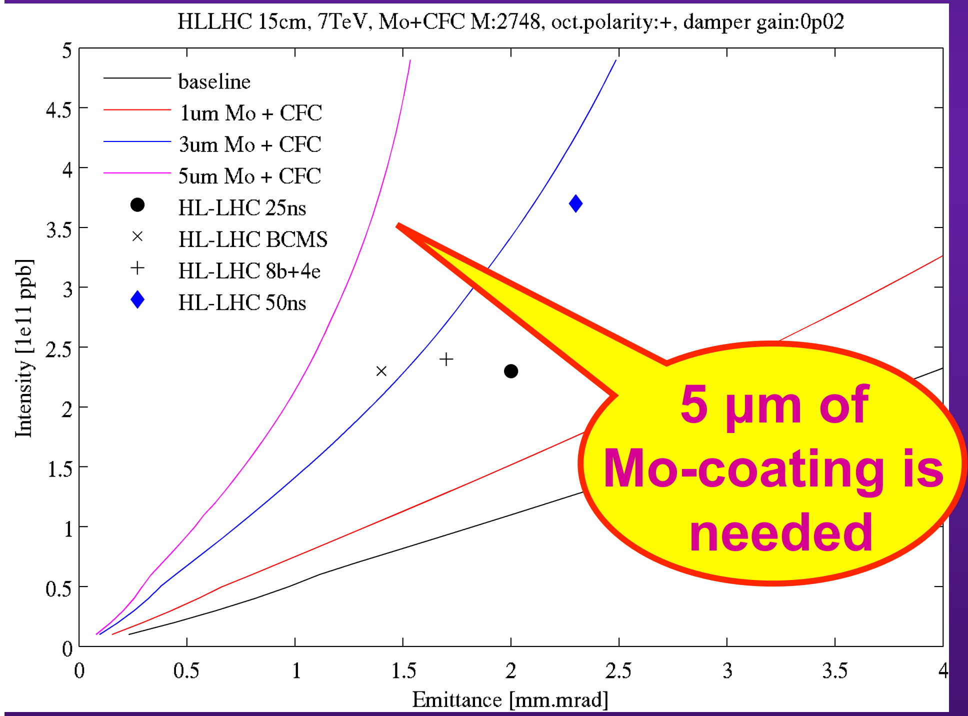
Preferred

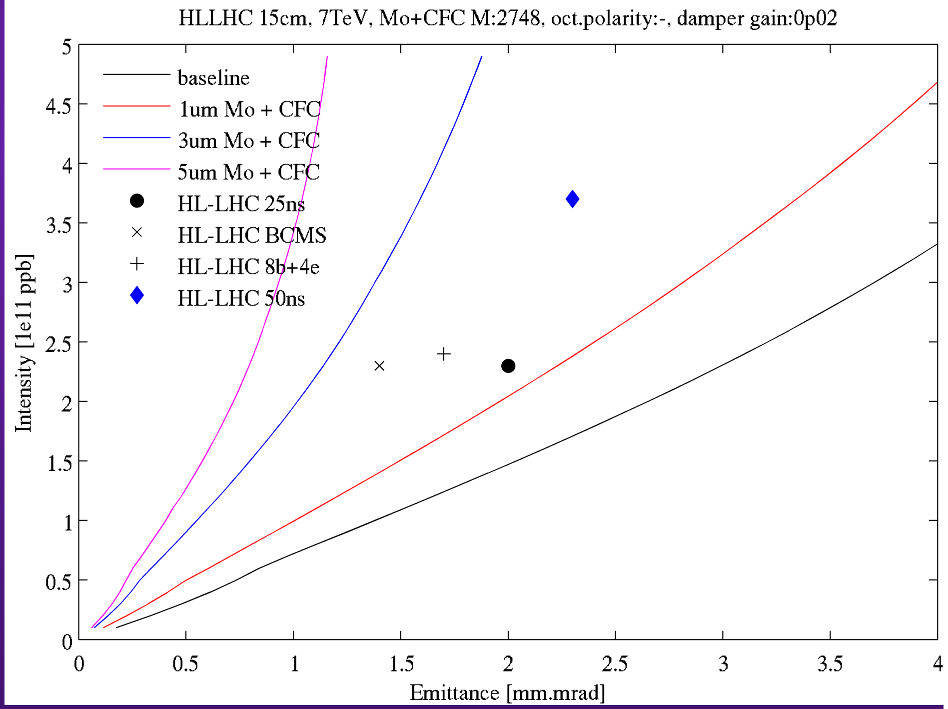




Mo-coating on CFC collimators

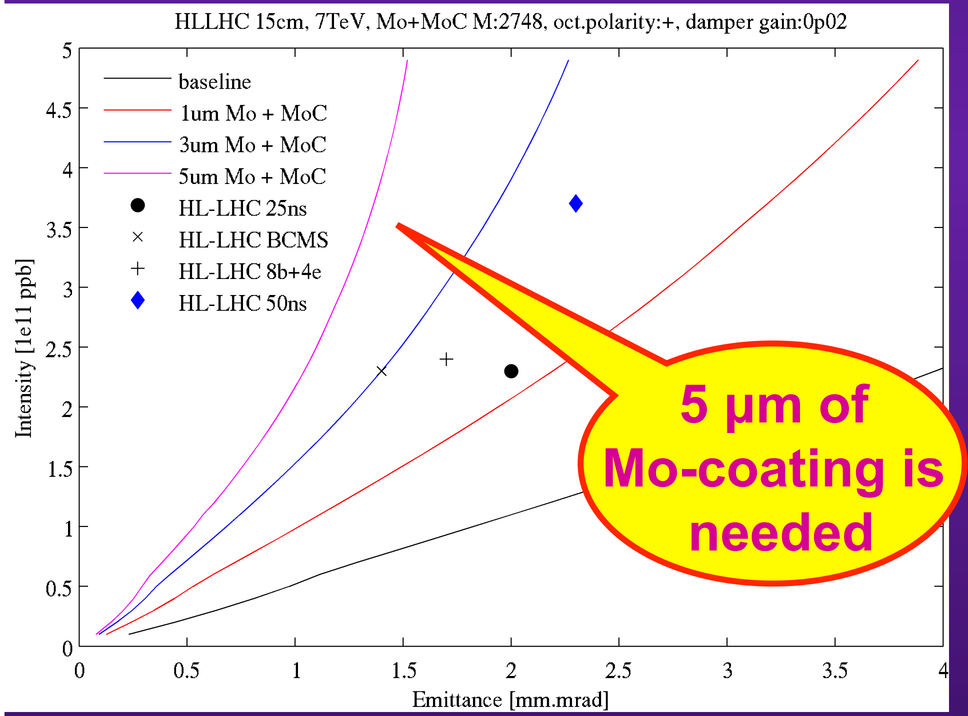
LOF > 0 | **LOF < 0**

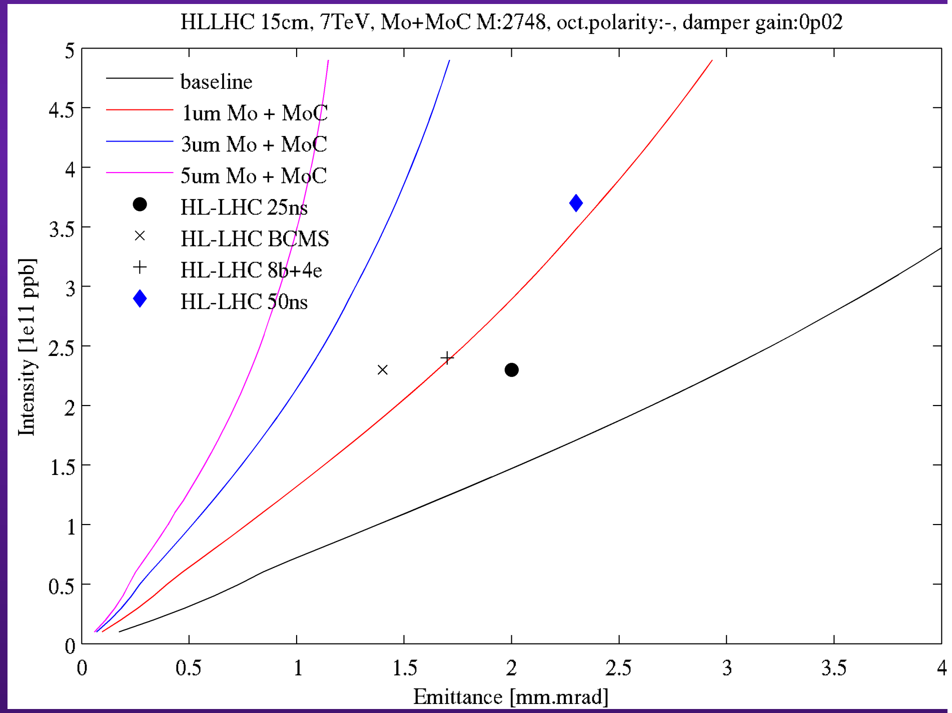




Mo-coating on MoC collimators

LOF > 0 | **LOF < 0**





- The recommendation was given in the PAC’09 paper http://cds.cern.ch/record/1235159/files/mo4rac02.pdf for the maximum allowed HOMs (for nominal LHC beam parameters: 1.15E11 p/b within 3.75 µm and using th… “…uit convention”)

From all the Crab Cavities

$$\frac{\beta_{CC}}{\beta_{av}} \times R_{HOM} << 1\,\mathrm{G\Omega/m}$$

“A reasonable target would be to have a margin of 2 orders of magnitude” mentioned in the paper

- $$\frac{\beta_{CC}}{\beta_{av}} \approx \frac{3600}{70} \approx 51$$

$$N_{CC\,/\,plane} = 8$$

=> $$R_{HOM\,/\,CC} << 2.5\,\mathrm{M\Omega/m}$$

Similar to FrankZ et al. (2008)

- Updating this to the HL-LHC parameters (2.2E11 p/b within 2.5 μm), yields

$$R_{HOM\,/\,CC} << 1 \text{ M}\Omega/\text{m}$$

- In the paper, a particular trapped mode was considered (with Q' = 0 and no transverse damper)

$$f_r = 800 \text{ MHz} \qquad Q = 1000$$

$$\frac{3000}{70} \times R \approx 86 \text{ M}\Omega/\text{m}$$

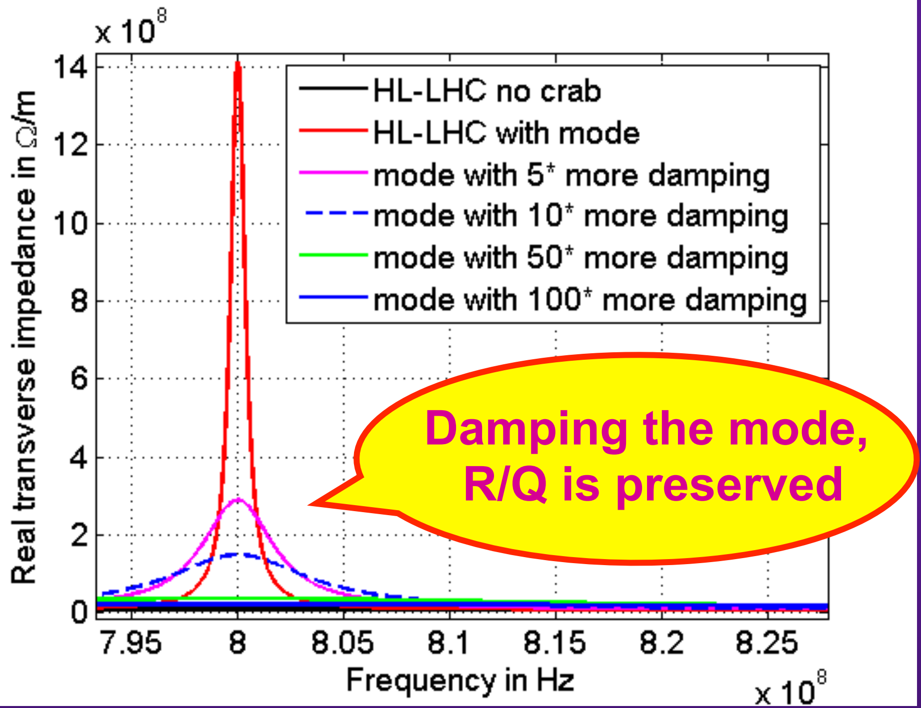
and the imaginary part of the tune shift obtained was: ~ - 0.09E-4

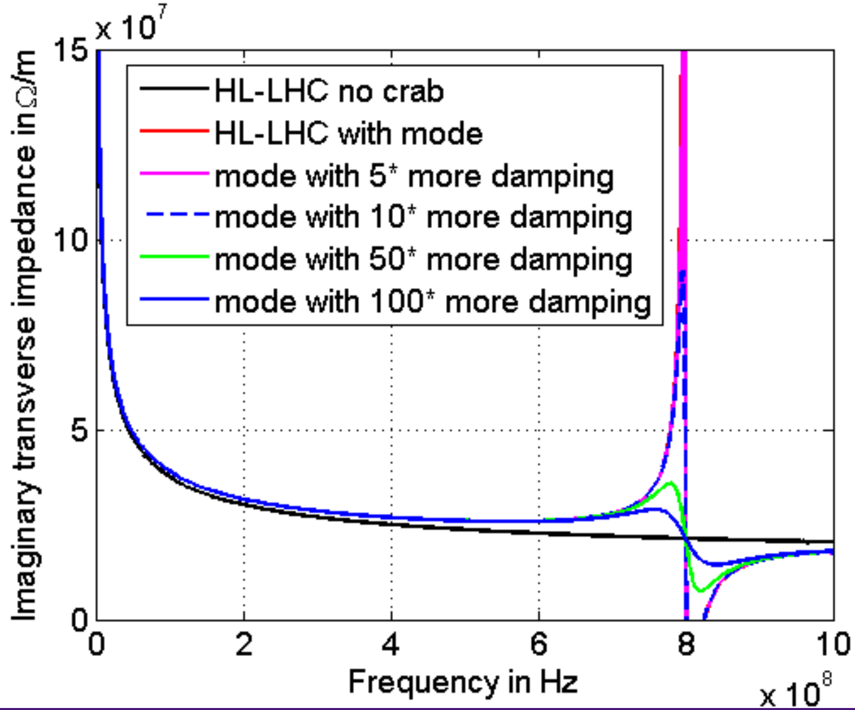
- Scaling to HL-LHC parameters (2.2E11 p/b), using the updated beta function at the Crab Cavities (3.6 km) and using the following mode (close to critical modes from the list shown by N. Biancacci)

$$\frac{3600}{70} \times R = 1.4 \text{ G}\Omega/\text{m}$$

$$f_r = 800 \text{ MHz}$$

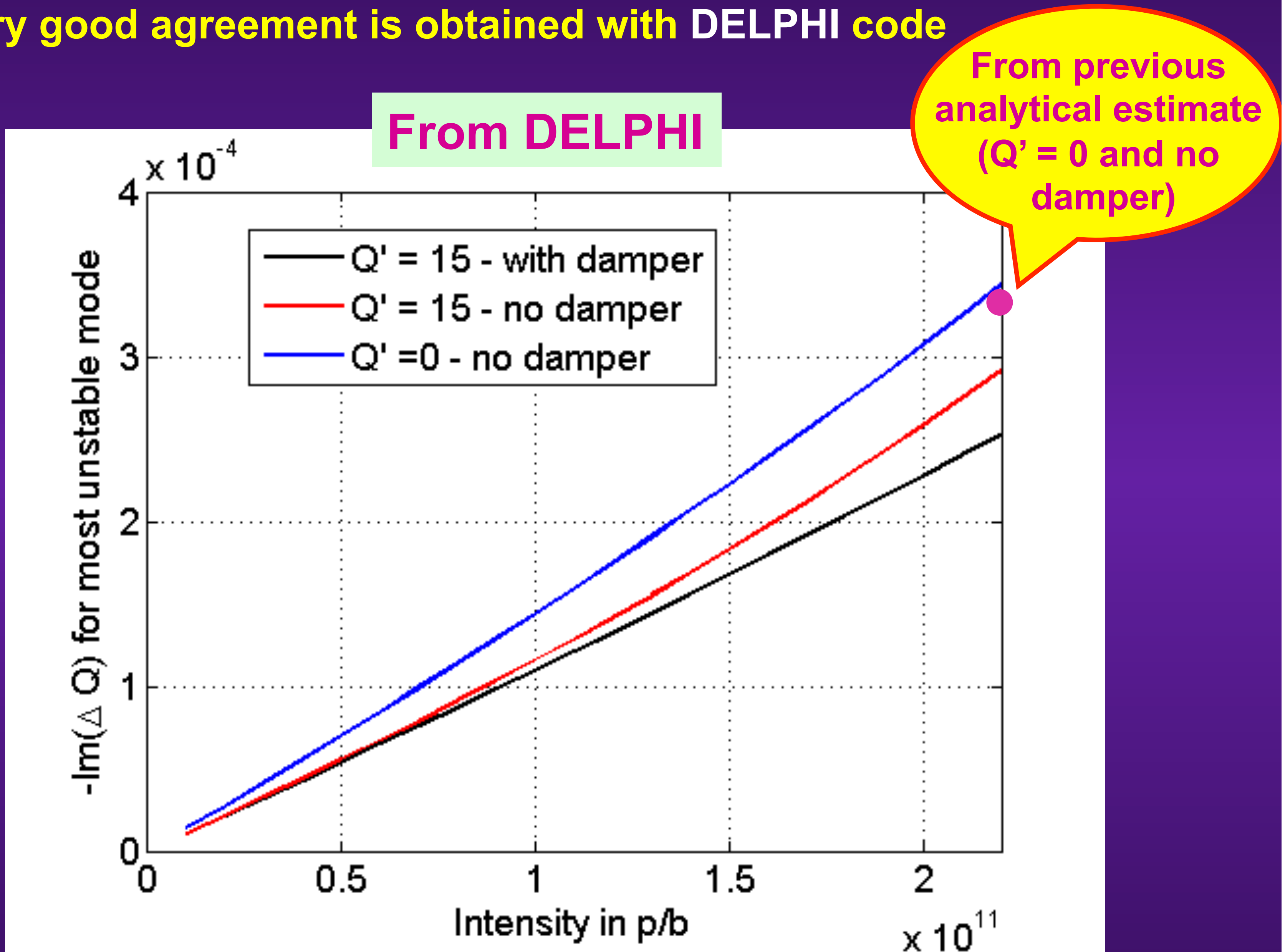
$$Q = 1000$$



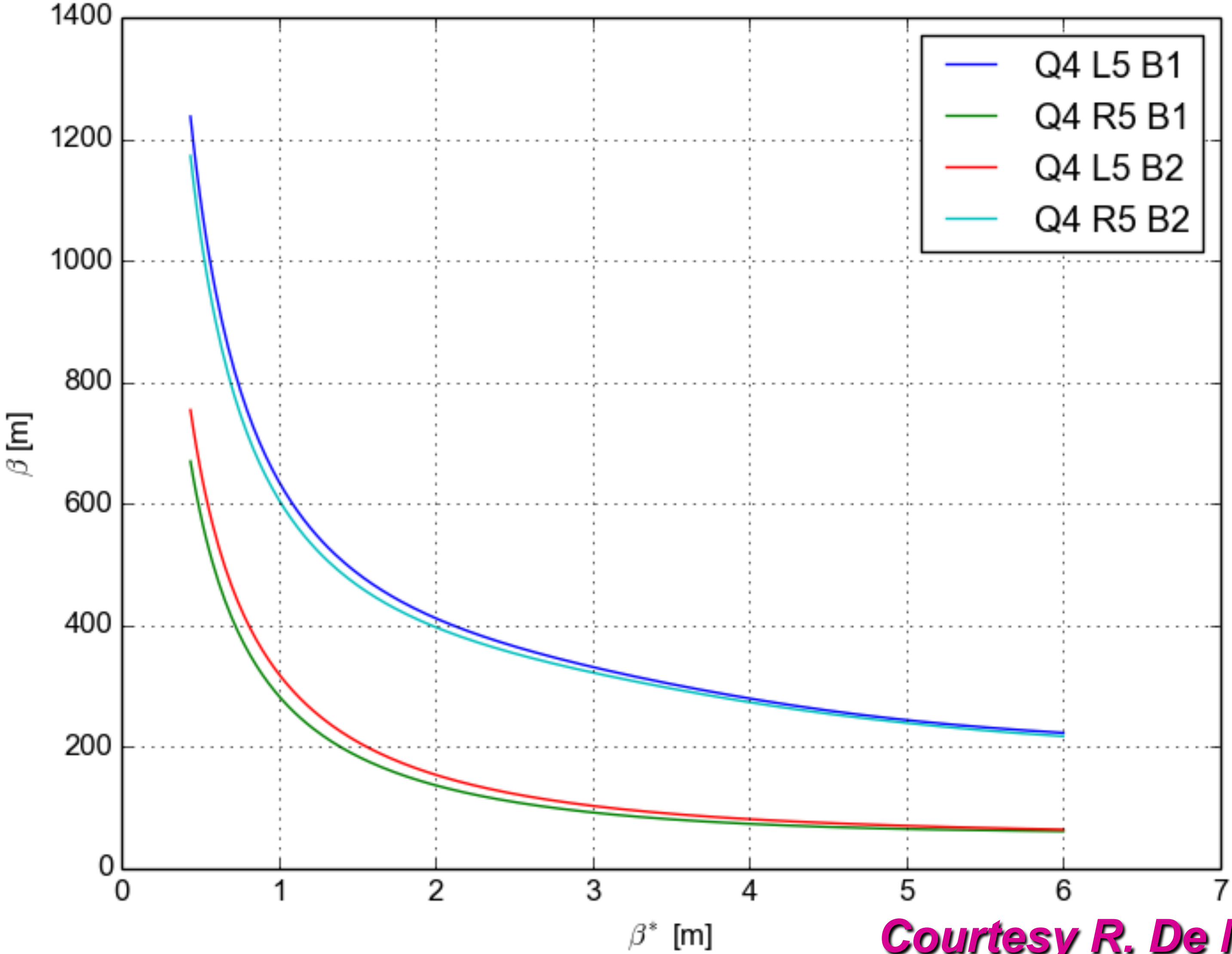


… the following imaginary part of the tune shift is obtained: ~ - 3.3E-4

=> A very good agreement is obtained with DELPHI code



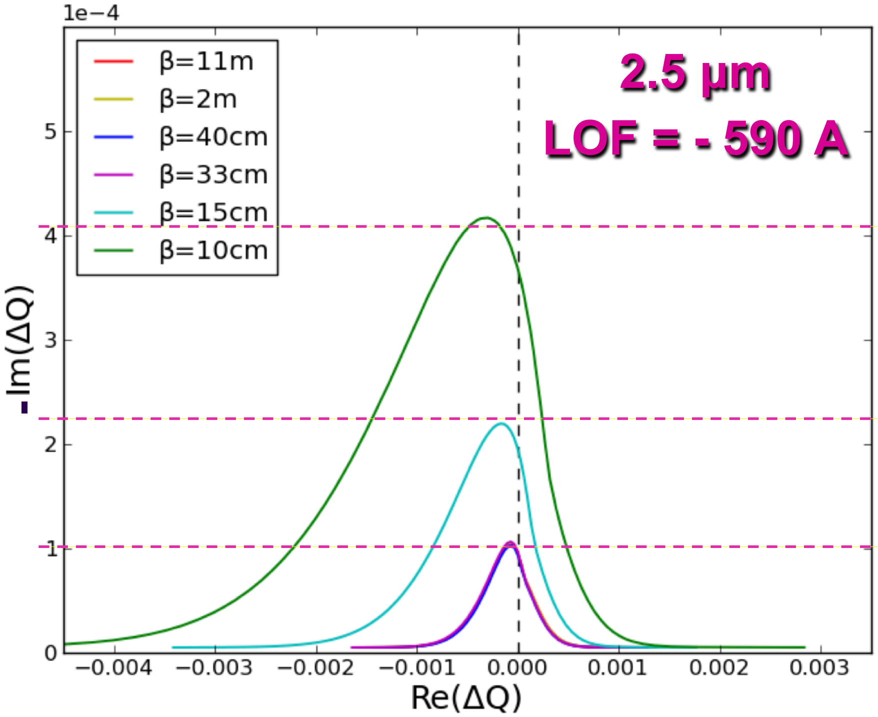
Beta at the crab cavity location (Q4)
=> Variations during squeeze of IR1/IR5 of HLLHCV1.0



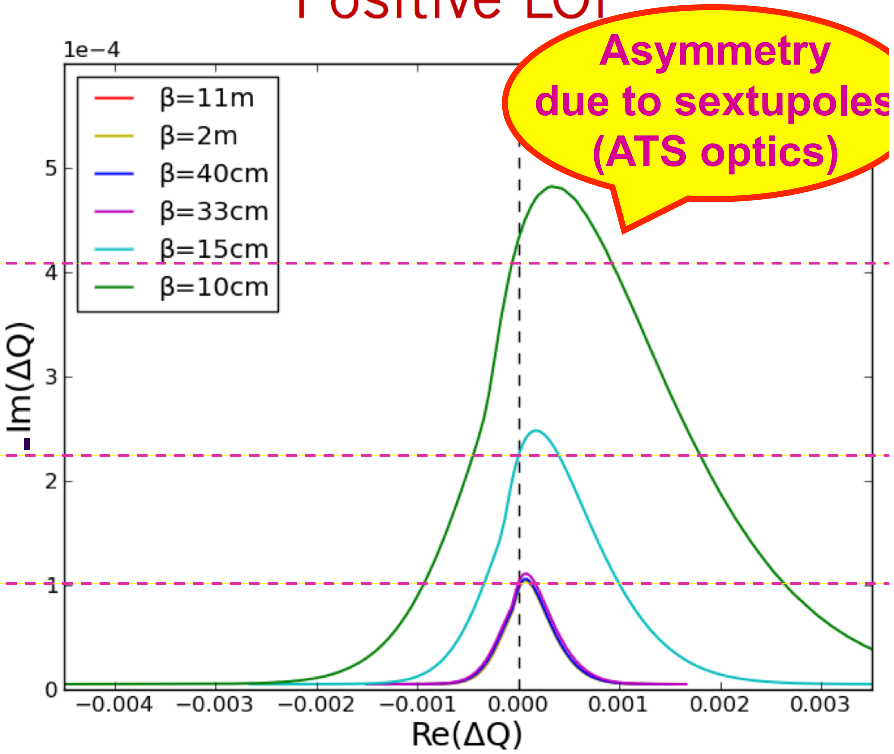
Courtesy R. De Maria

Without BBHO

Negative LOF



Positive LOF

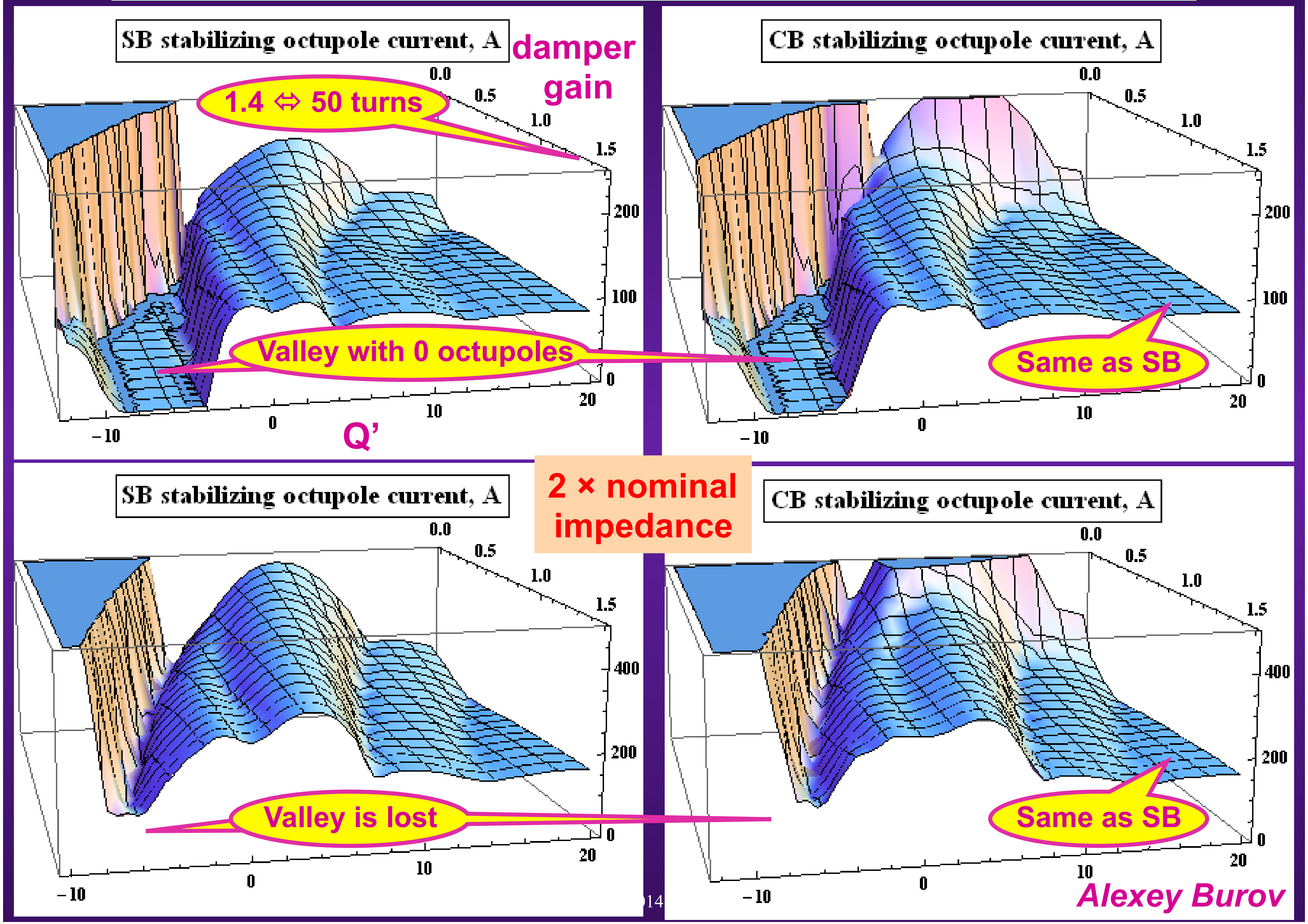


- **Some analyses about the tune spread and stability diagram in the presence of both**
  - **BBLR and octupoles**
  - **Space charge and octupoles**

  https://espace.cern.ch/be-dep/ABP/HSC/Meetings/HSC_EM_27-08-14_Final.pdf

- **Landau damping with an RFQ => https://espace.cern.ch/be-dep/ABP/HSC/Meetings/MSchenk_LandauDampingRFQ_HSC_291014.pdf**

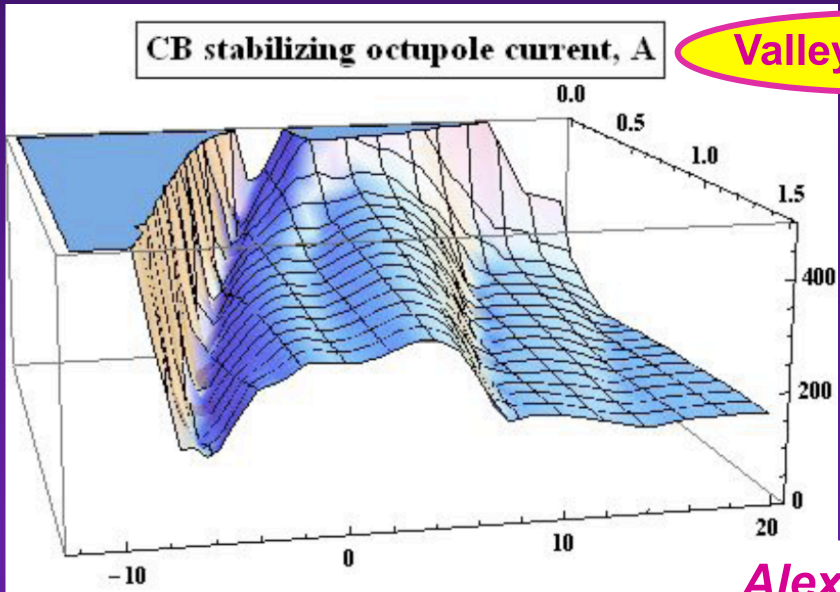
LHC 2012 case => 50 ns beam, ~ 1.5E11 p/b within ~ 2 microm



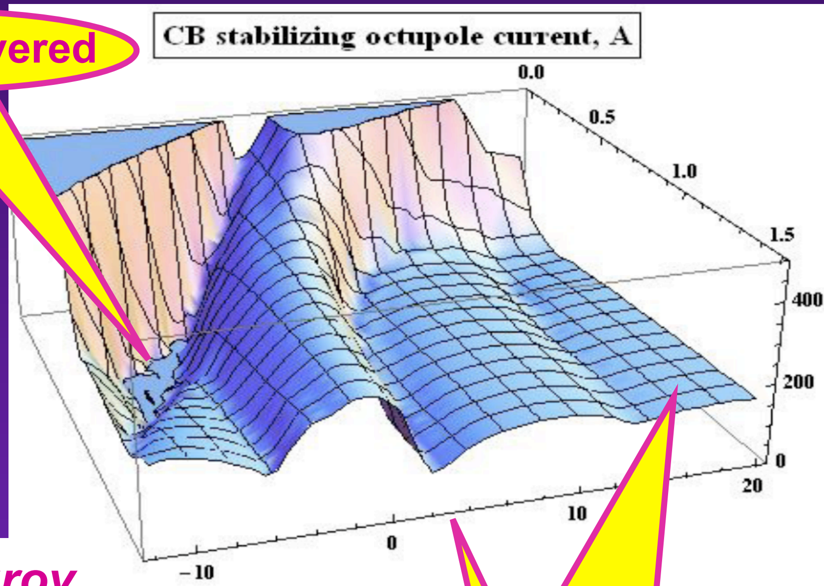
Alexey Burov

LHC 2012 case => 50 ns beam, ~ 1.5E11 p/b within ~ 2 microm + 2 times imped

- Old ADT



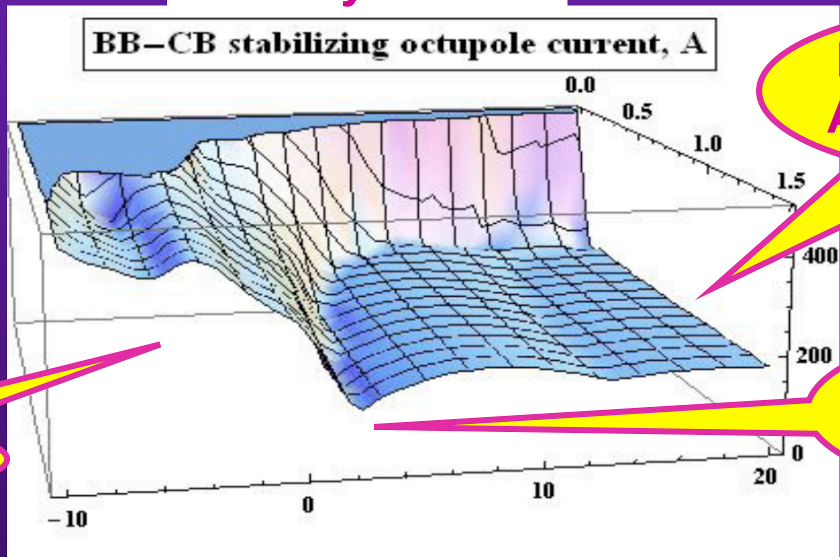
New (bbb – flat gain) ADT



Valley recovered

Alexey Burov

New (bbb – flat gain) ADT + Beam-Beam



incoherent $dQ_{bb} / Q_s|_{IR1,5} = \pm 1.1; \quad d\phi_{15} = \pi$

No difference on AlexeyB's plateau

Valley lost again…

Chroma. of ~ 2 units good again…

- **Single-beam stability: Comparison between measurements (average) and HEADTAIL simulations => Factor ~ 4**