Brightness Curve Simulations

F. Asvesta, F. Antoniou, H. Bartosik

S. Albright, C. Bracco, E. Renner

Overview

— Working Point Choice
  - Beam Loss Mechanism

— Brightness Curve at 160 MeV

— Summary & Outlook

Working Point Choice : Recap of Half-Integer Studies

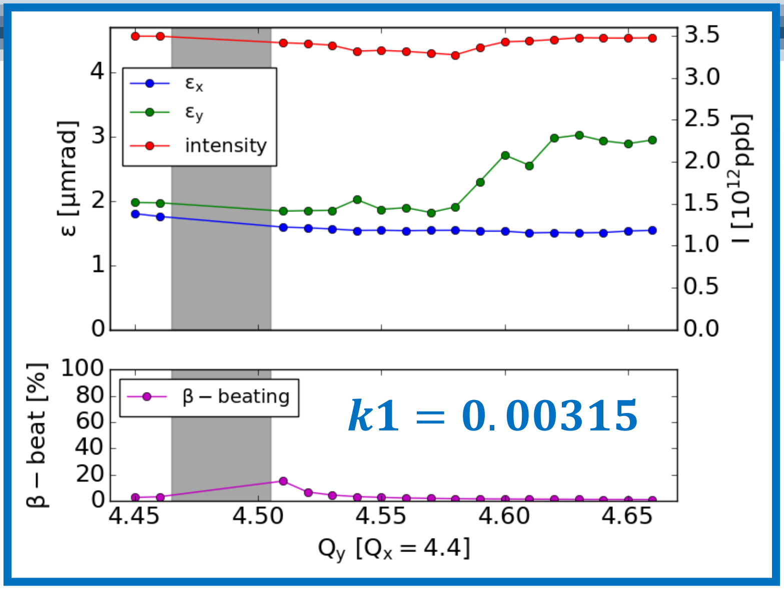
Below the half integer:

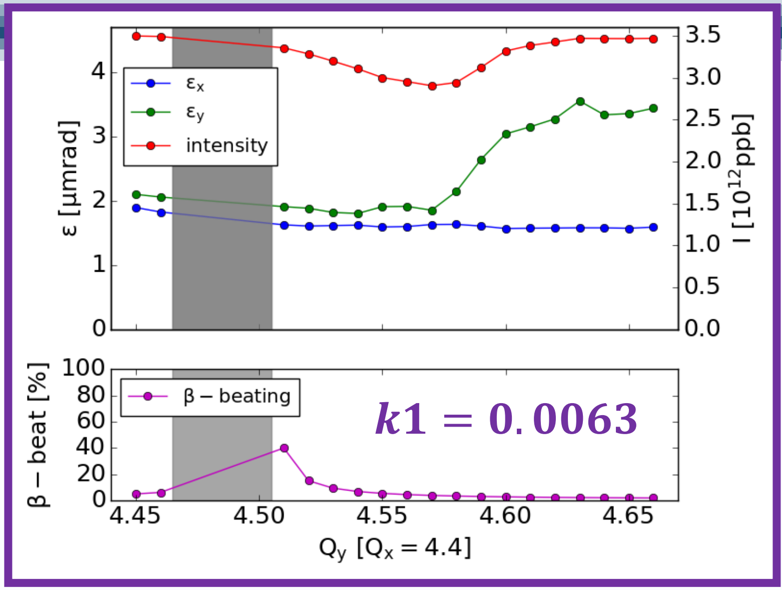
1. **<1% losses** regardless of error
2. **Smaller beta-beating** for all errors
3. **Overall blow-up smaller** for the same loss limit

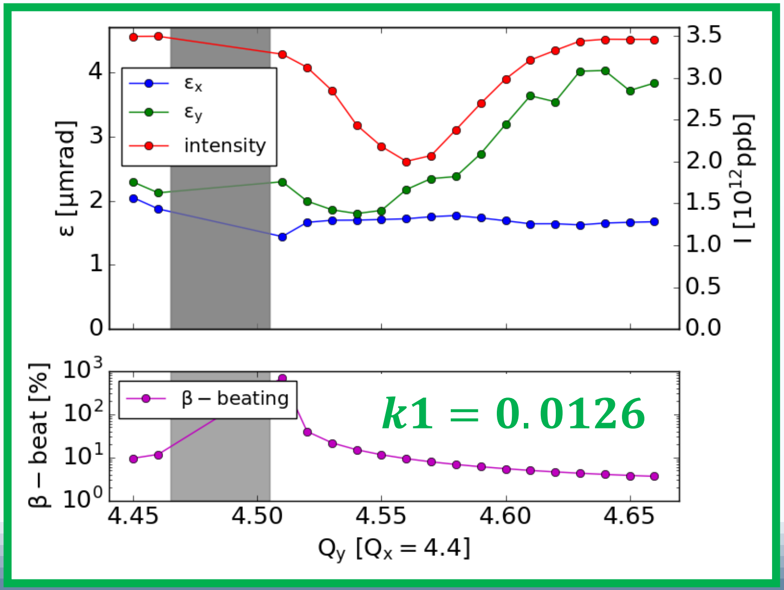
Questions raised in the previous meeting

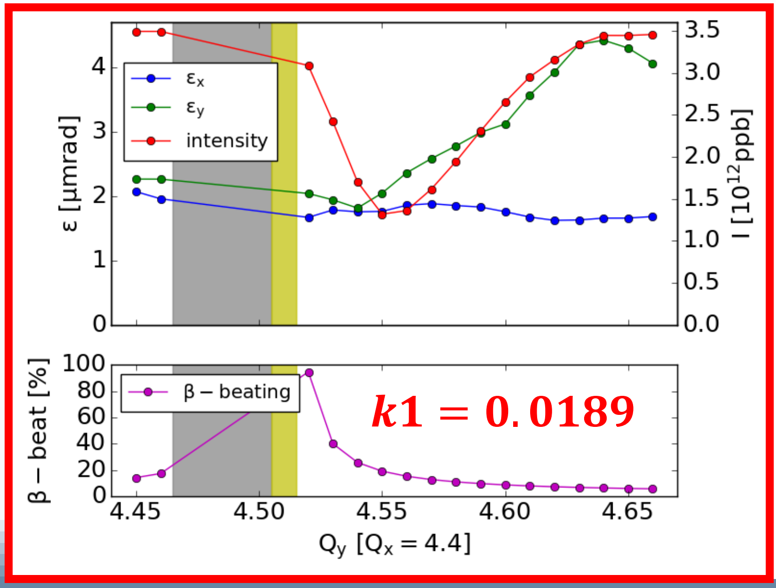
*Could we allow **losses above the half integer** if we getter smaller emittances?*

*Could we allow **losses** of uncaptured beam to get smaller emittances **below the half integer**?*









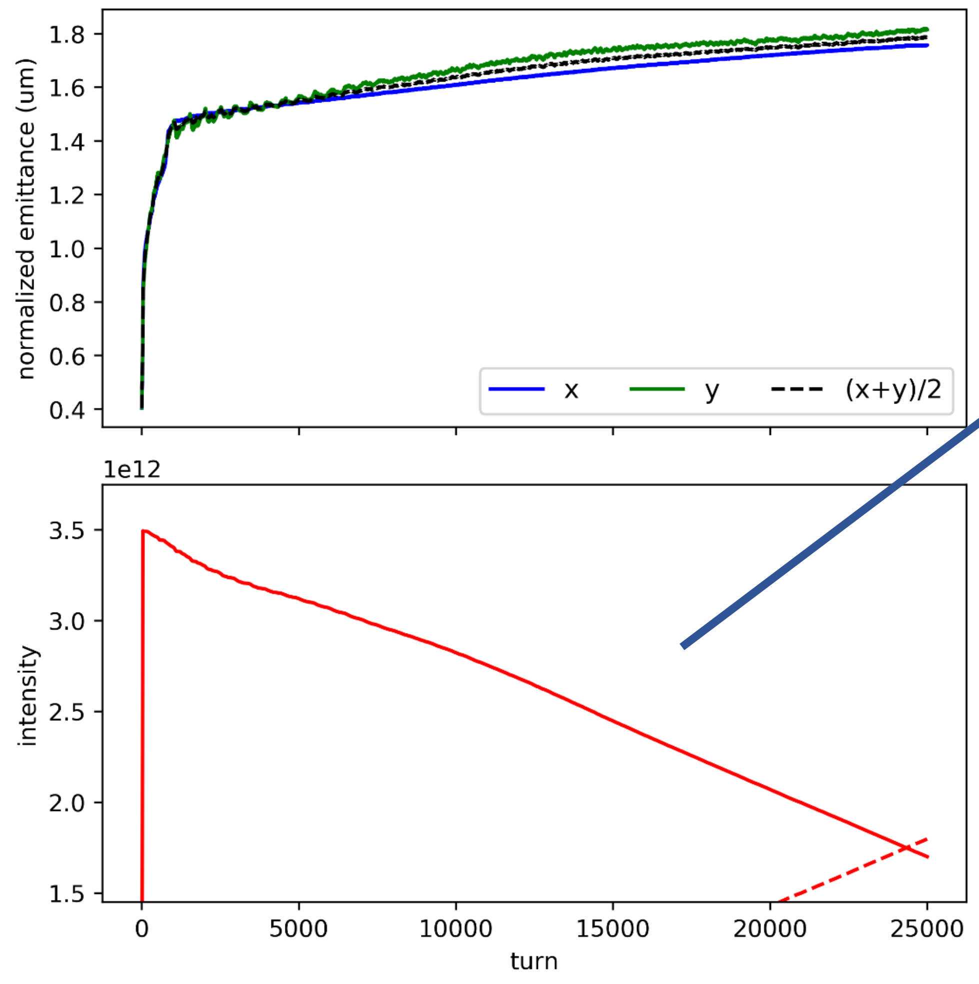
Can we tolerate losses???

Resonances

Uncaptured Beam

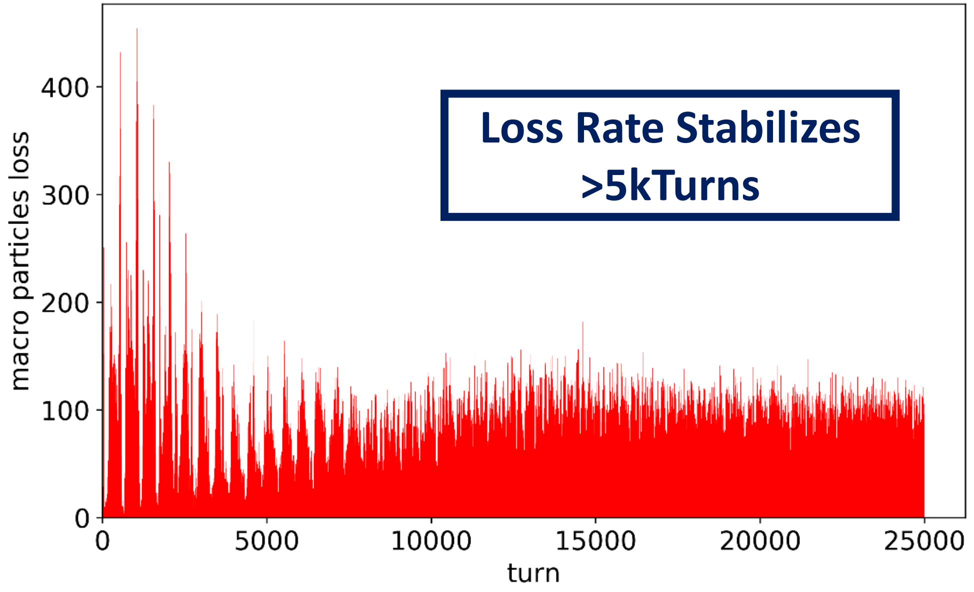
Losses From Half Integer Resonance

In the presence of quadrupolar error



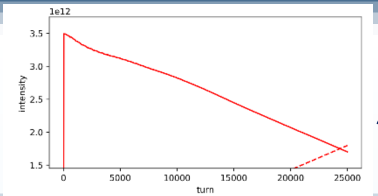
Continuous Losses

Simulation Parameters	
Chopping Factor	**0.6**
dE_{rms}	**0.35 MeV**
Working Point	Q_x**=4.40** , Q_y**=4.54**
Quad Error	K1=**0.0189**



Loss Rate Stabilizes >5kTurns

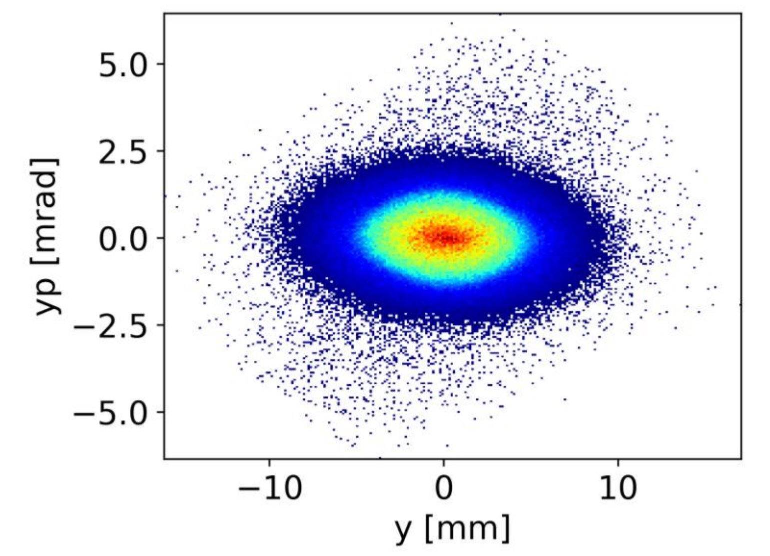
Losses From Half Integer Resonance

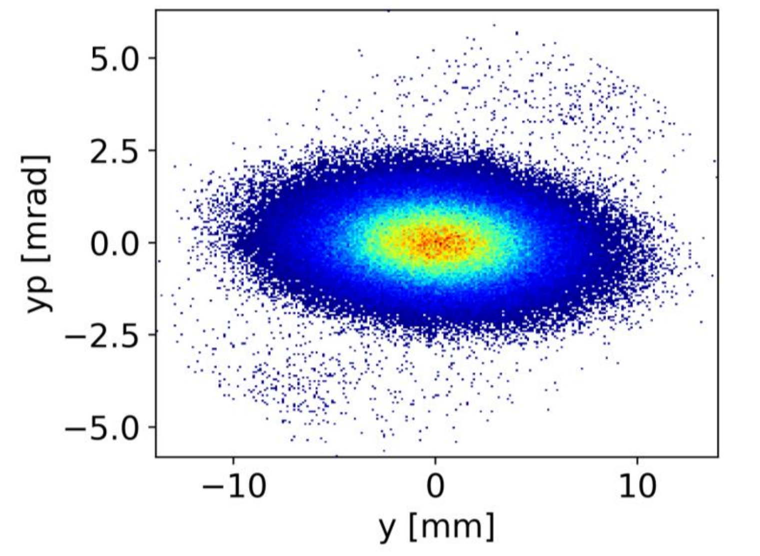


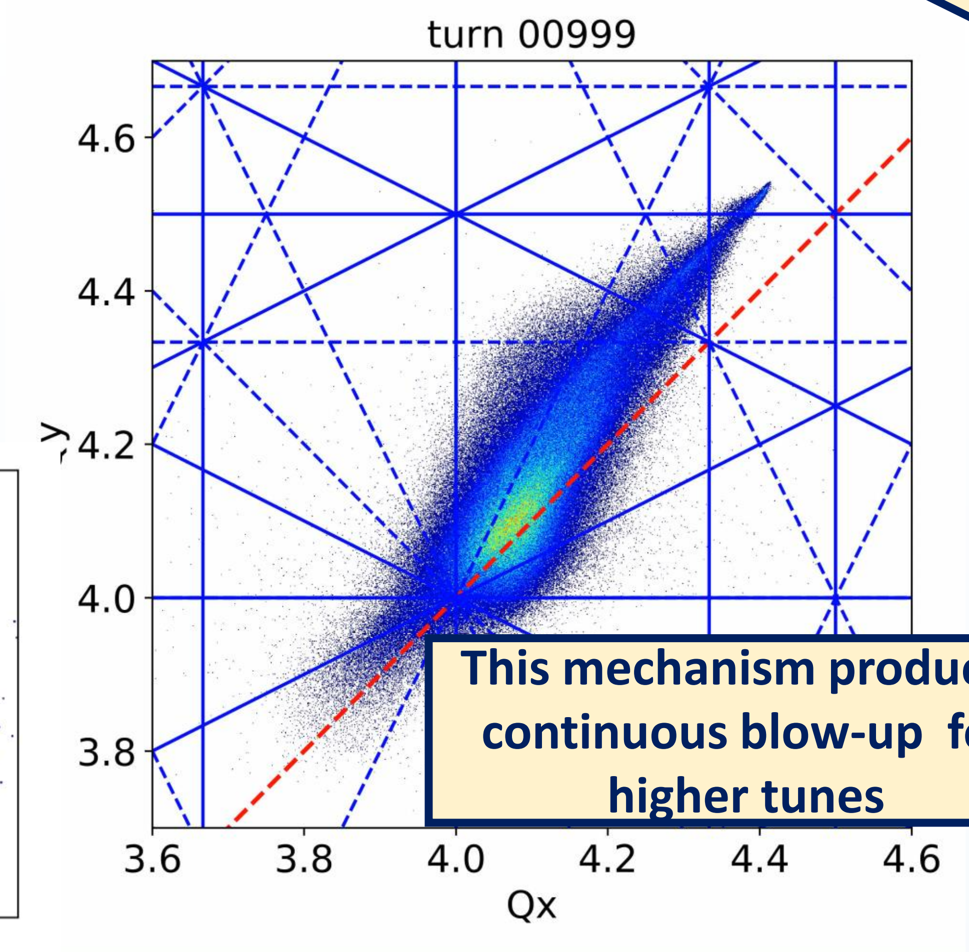
In the presence of quadrupolar error

Loss Mechanism

- Particles are **captured** by the half integer resonance creating **halo** on the y-plane
- **Halo** is scraped on the aperture creating **losses**
- Space charge tune **spread shrinks** pushing more particles on the resonance



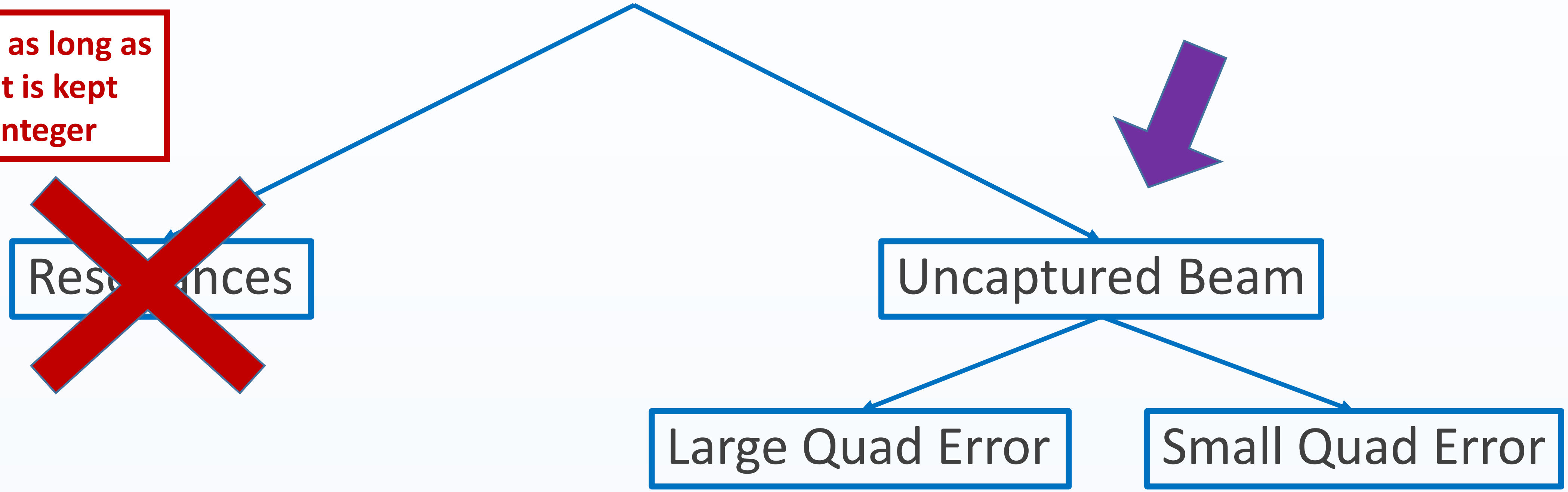




This mechanism produces continuous blow-up for higher tunes

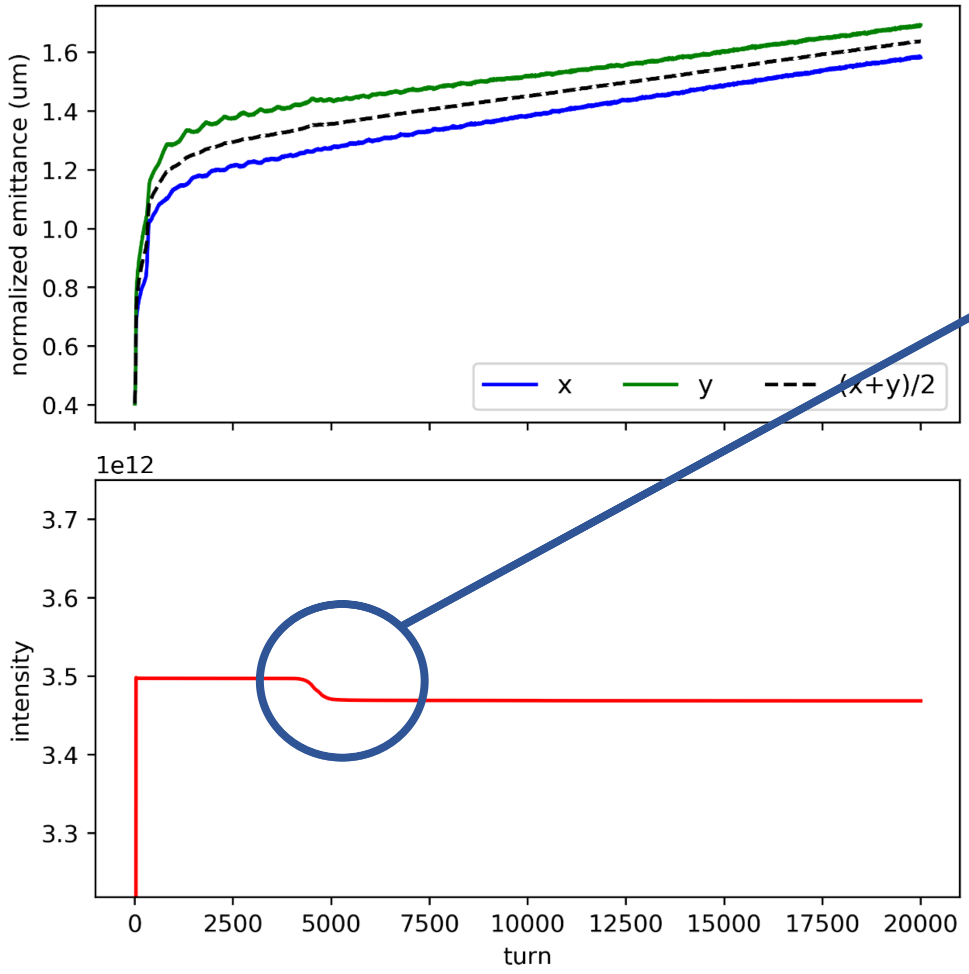
Can we tolerate losses???

Losses continue for as long as the working point is kept above the half integer



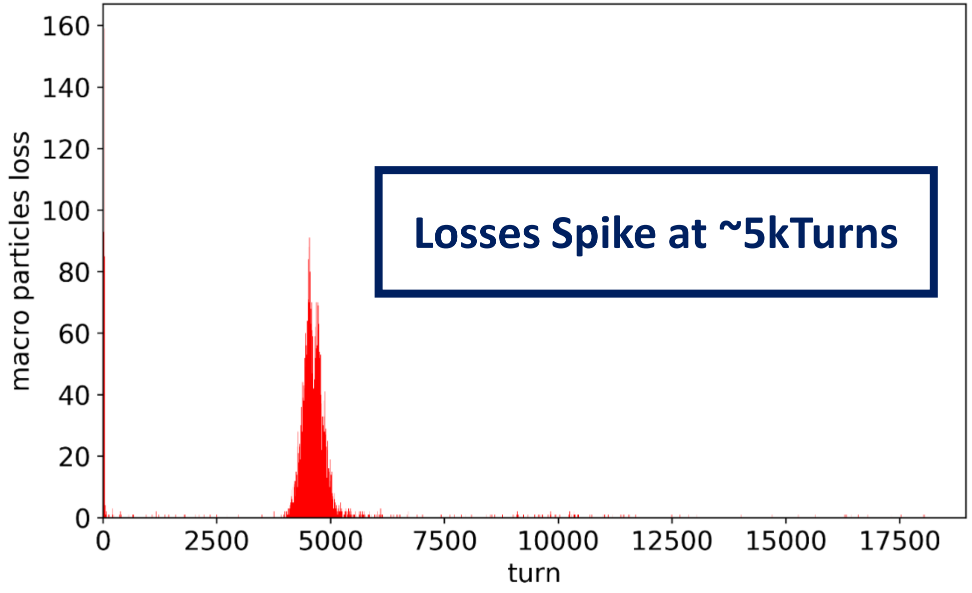
Losses From Uncaptured Beam

In the presence of **large** quadrupolar error

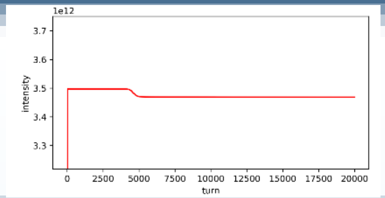


Step-Like Losses

Simulation Parameters	
Chopping Factor	**0.7**
dE_{rms}	**0.44 MeV**
Working Point	Q_x=**4.40** , Q_y=**4.45**
Quad Error	K1=**0.0189**



Losses From Uncaptured Beam

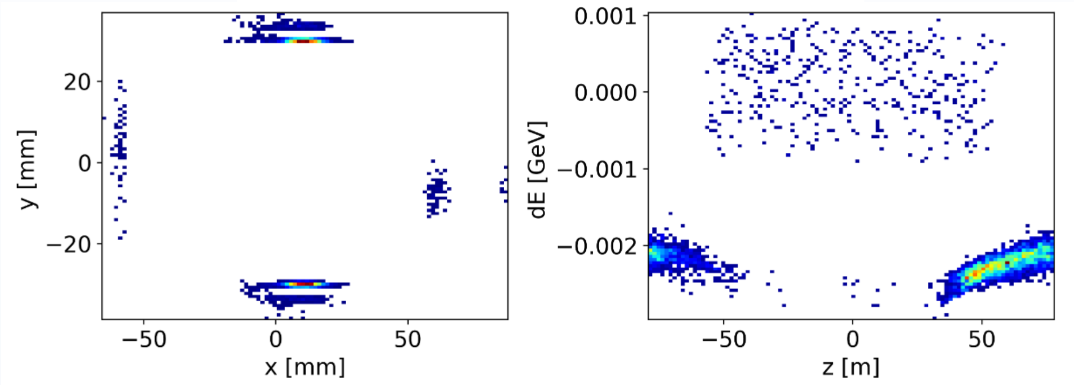


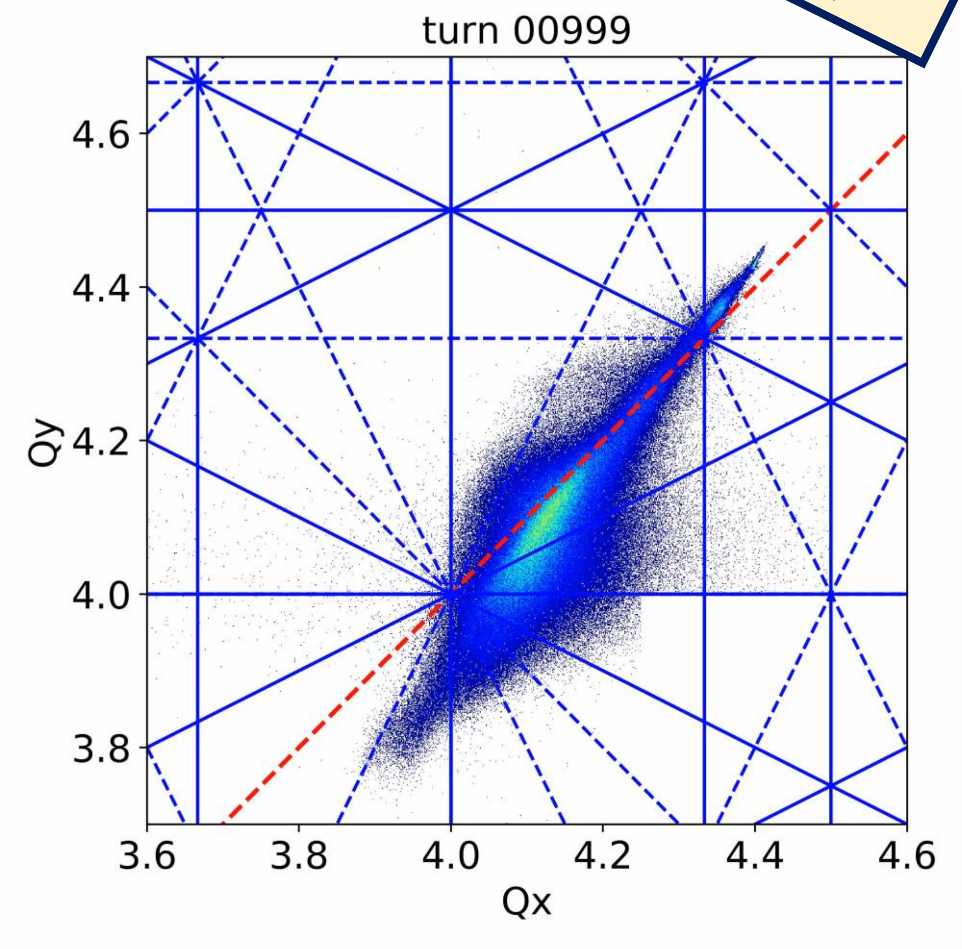
In the presence of large quadrupolar error

Loss Mechanism

- Particles left out of the bucket **move with the beam** in the **flat** bottom
- During the **ramp** uncaptured beam doesn't change energy resulting to **different** orbit and **tunes**
- Uncaptured particles get lost on the **vertical** aperture as they get captured by the **half integer resonance**

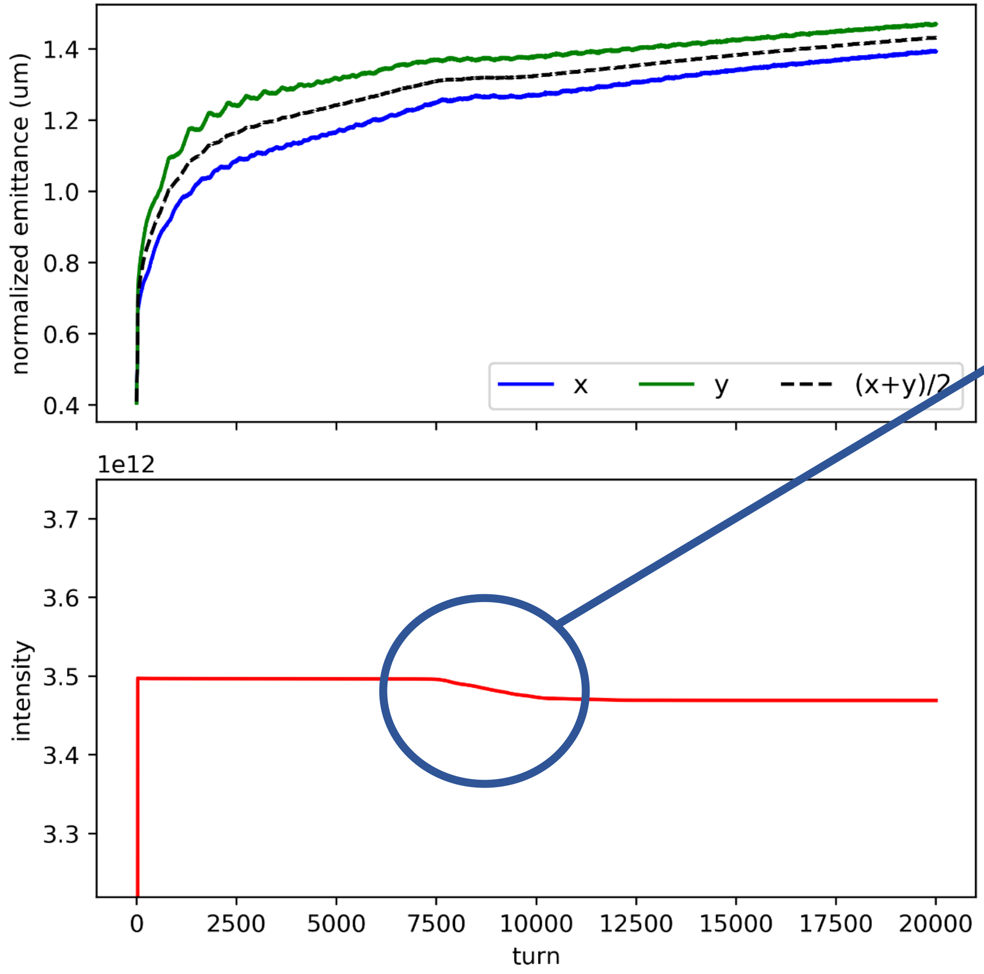
Lost Particles up to 5k Turns





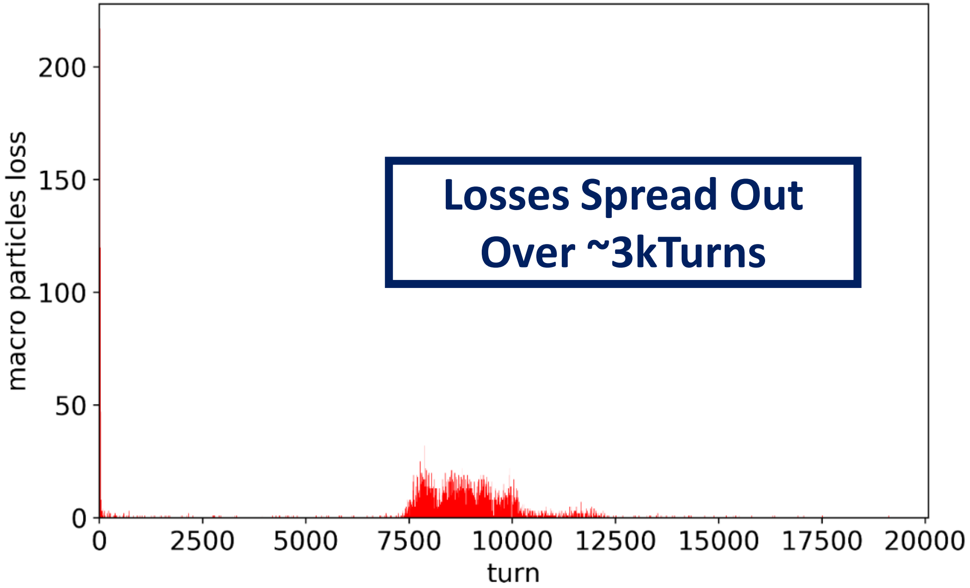
Losses From Uncaptured Beam

In the presence of **small** quadrupolar error

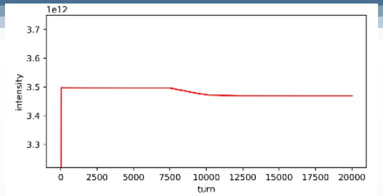


Step-Like Losses

Simulation Parameters	
Chopping Factor	**0.7**
dE_{rms}	**0.44 MeV**
Working Point	Q_x=4.40 , Q_y=4.45
Quad Error	K1=**0.00315**



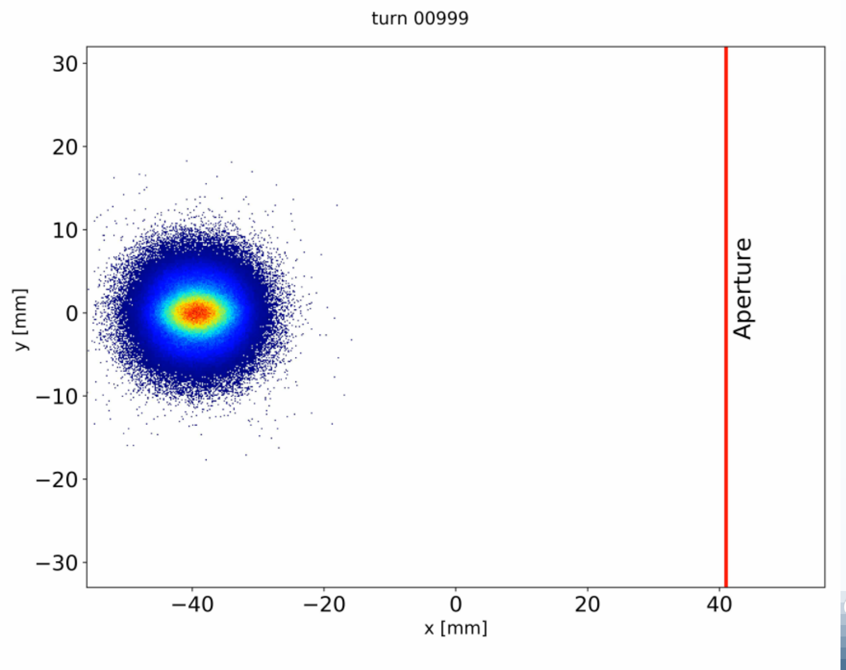
Losses From Uncaptured Beam

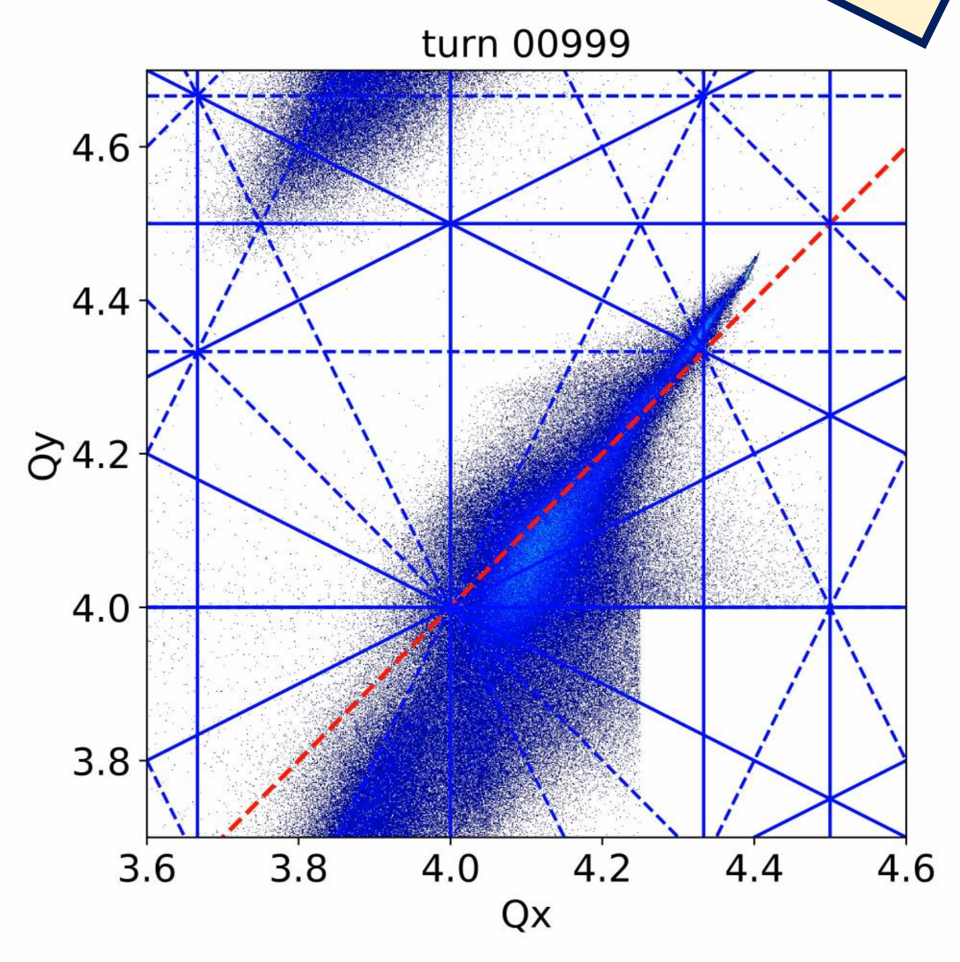


In the presence of small quadrupolar error

Loss Mechanism

- Particles left out of the bucket **move with the beam** in the **flat** bottom
- During the **ramp** uncaptured beam doesn't change energy resulting to **different orbit** and tunes
- Uncaptured particles get lost on the **horizontal** aperture





Can we tolerate losses???

Losses continue for as long as the working point is kept above the half integer

Resonances

Losses of uncaptured particles ONLY regardless of error could be tolerated ~1-2%

Uncaptured Beam

Brightness Curve at 160 MeV

→Setup for **0% losses**: **Larger longitudinal line density**

→Setup allowing **1-2% losses** of uncaptured beam: **Lower longitudinal line density**

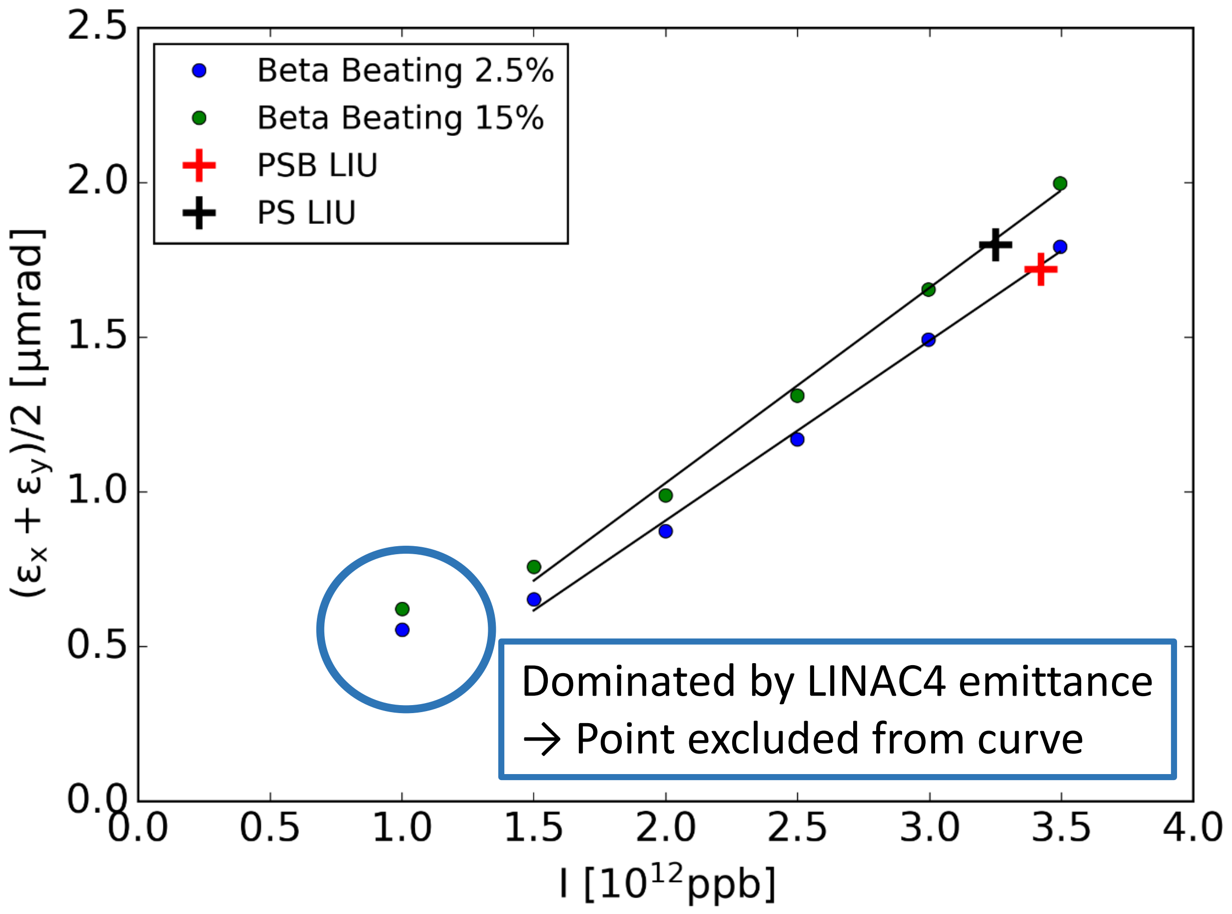
No Beam Loss Setup

Simulation Parameters						
Linac4						
$\varepsilon_x/\varepsilon_y$	$0.4\ mm\ mrad$					
I	$25\ mA$					
Chopping Factor	**0.6**					
dE_{rms}	**0.35 MeV**					
PSB						
Cycle	Flat 1					
Injected Intensity [10^{12} ppb]	1	1.5	2	2.5	3	3.5
Accumulation [Turns]	**11**	**16**	**22**	**27**	**32**	**38**
Simulation time	20 kTurns					
Working Point	Q_x**=4.40** , Q_y**=4.45**					
Quad Error	k1=**0.00315 (2.5% Beta-beat)** /**0.0189 (15% Beta-beat)**					

No losses

- The **brightness** depends on the **quadrupolar error**
  → how well we can **compensate the beta beating**

- Beta-beating ≤ 2.5%
  — Marginally on the **PSB-LIU** target
- Beta-beating ≤ 15%
  — Marginally on the **PS-LIU Injection** target



Allowing ~1-2% Beam Loss Setup

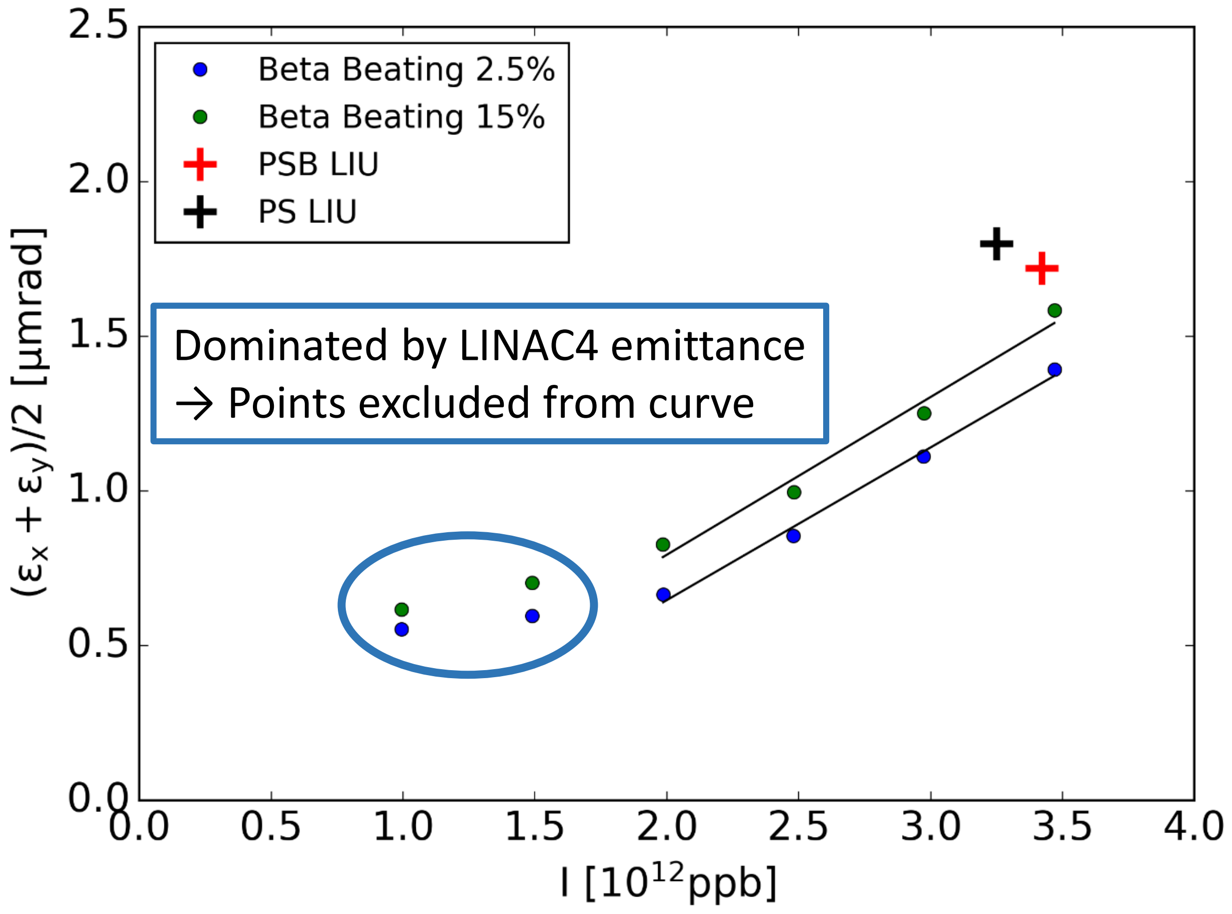
Uncaptured Beam!!!!

Simulation Parameters						
Linac4						
$\varepsilon_x/\varepsilon_y$	$0.4\ mm\ mrad$					
I	$25\ m$A					
Chopping Factor	**0.7**					
dE_{rms}	**0.44 MeV**					
PSB						
Cycle	Flat 1					
Injected Intensity [10^{12} ppb]	1	1.5	2	2.5	3	3.5
Accumulation [Turns]	**10**	**14**	**19**	**23**	**28**	**32**
Simulation time	20 kTurns					
Working Point	**Q_x=4.40 , Q_y=4.45**					
Quad Error	k1=**0.00315 (2.5% Beta-beat)** /**0.0189 (15% Beta-beat)**					

~1-2% losses

Uncaptured Beam!!!!

- The **brightness** depends on the **quadrupolar error**
  → how well we can **compensate the beta beating**
- The **lower longitudinal line density** contributes to **better brightness**
- **Below** the **LIU** target for the errors tested



Summary & Outlook

- Working points **below the half integer** are preferable as they allow better control of the beam regardless of the quadrupolar error
- Losses from **resonances cannot be tolerated** as they continue throughout the cycle
- Losses of **uncaptured beam** could be tolerated (<1-2% level) as the larger longitudinal line density **favors brightness**
- The **brightness curve at 160 MeV** gives some **margin** for additional error studies only in the case of **lower longitudinal line density,** allowing 1-2% off-bucket losses

Future Studies

- **Benchmark** the simulations at **50 MeV** using data of previous years
- Track using a more **realistic longitudinal space charge model**
- Use a more **realistic longitudinal distribution** for better assessing capture losses
- Use a more **realistic machine model** including non-linear errors

Thank you!

Back-up

Small Error

- Qy=4.66