


Further Analysis of the p-Pb Pilot Run

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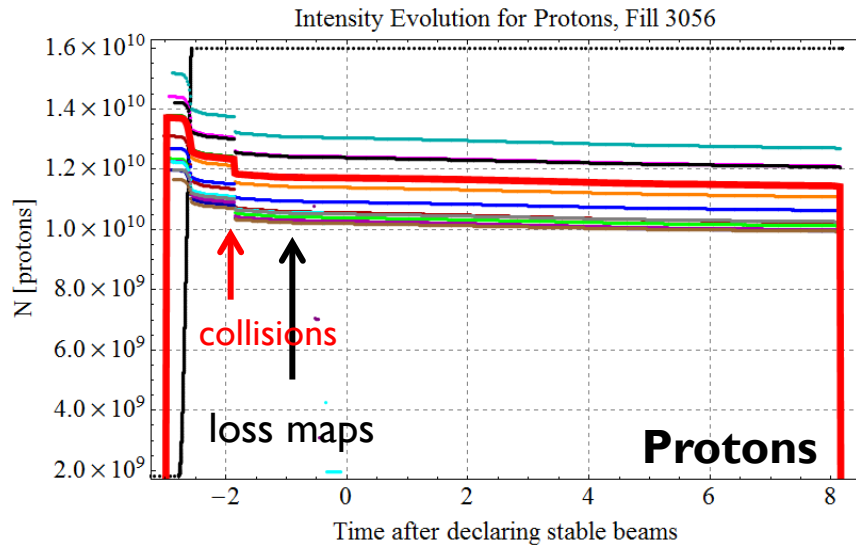
Injection Scheme

- ▶ Injection of 15 p and 15 Pb bunches
- ▶ 2 bunch/beam used for loss maps done before stable beams
- ▶ **1 bunch/beam was non-colliding** 
- ▶ 12 bunches per beam left to provide 8 collisions per IP
- ▶ Injection optics - no squeeze
 - ▶ $\beta^* = 10$ and 11 m

INJECTIONS B1						INJECTIONS B2							
RFBucket	...	bu/batch	Bunch Int	...	RFBucket	...	bu/batch	Bunch Int	...
1	0	1	1	1	100	0	1	0	1	1	1	100	0
1001	0	1	1	1	100	0	1001	0	1	1	1	100	0
2001	0	1	1	1	100	0	2001	0	1	1	1	100	0
3001	0	1	1	1	100	0	3001	0	1	1	1	100	0
6001	0	1	1	1	100	0	5001	0	1	1	1	5	0
8941	0	1	1	1	100	0	8911	0	1	1	1	100	0
9941	0	1	1	1	100	0	9911	0	1	1	1	100	0
10941	0	1	1	1	5	0	10911	0	1	1	1	100	0
11941	0	1	1	1	5	0	11911	0	1	1	1	5	0
17851	0	1	1	1	100	0	17851	0	1	1	1	100	0
18851	0	1	1	1	100	0	18851	0	1	1	1	100	0
19851	0	1	1	1	100	0	19851	0	1	1	1	5	0
20851	0	1	1	1	5	0	20851	0	1	1	1	5	0

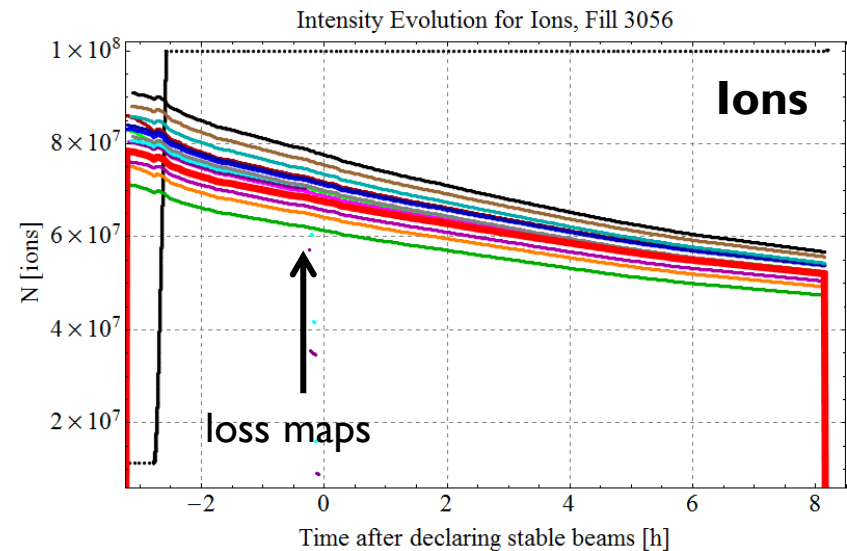
Parameter range at start of stable beams	Protons	Ions
Number of Particles per Bunch [particles]	$(1.0 \text{ to } 1.3) \times 10^{10}$	$(6 \text{ to } 8) \times 10^7$
Horizontal Emittance [$\mu\text{m}\cdot\text{rad}$]	2.0 to 3.5	1.3 to 1.5
Vertical Emittance [$\mu\text{m}\cdot\text{rad}$]	1.0 to 2.0	0.8 to 1.0
Bunch Length [cm]	11.5	11

Intensity Evolution

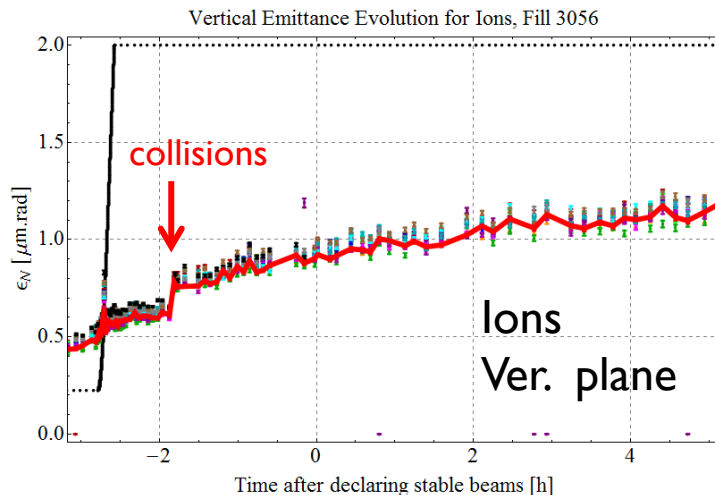
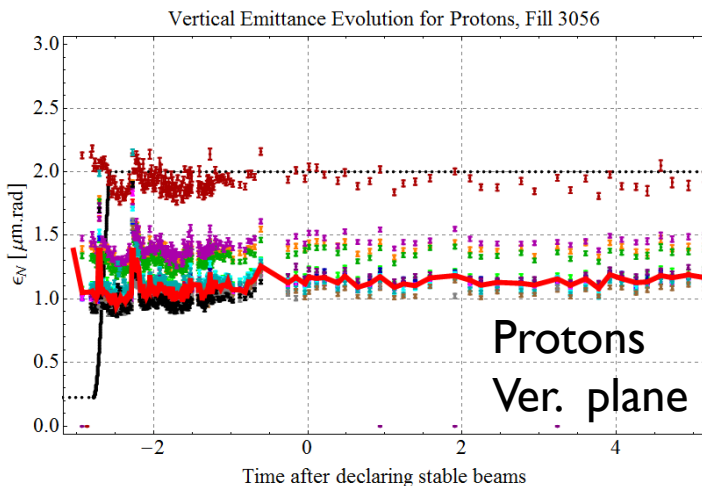
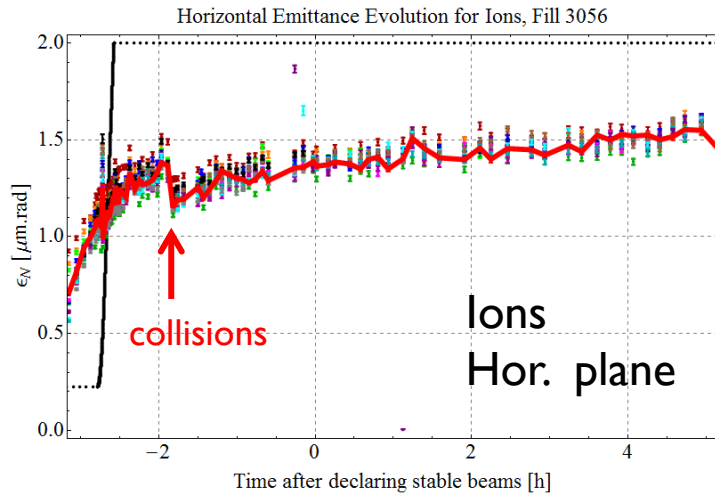
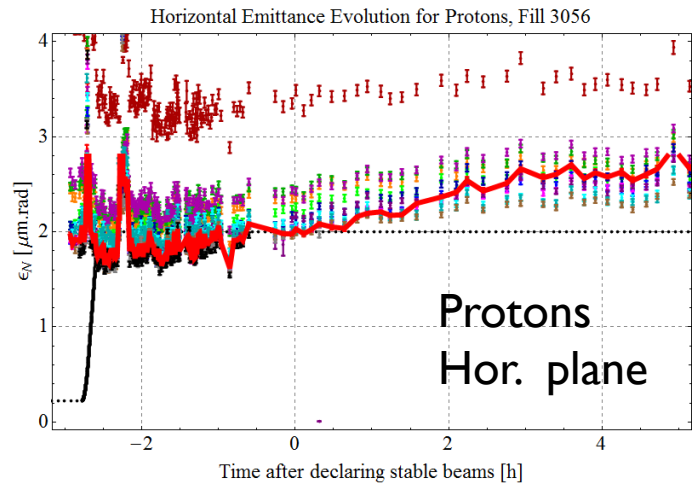


All bunches seem to behave similarly including the non-colliding bunch

- ▶ Time = 0 corresponds to declaring STABLE BEAMS
- ▶ Thick red bunch is non-colliding
- ▶ The black dots are the energy variation (in arbitrary units)



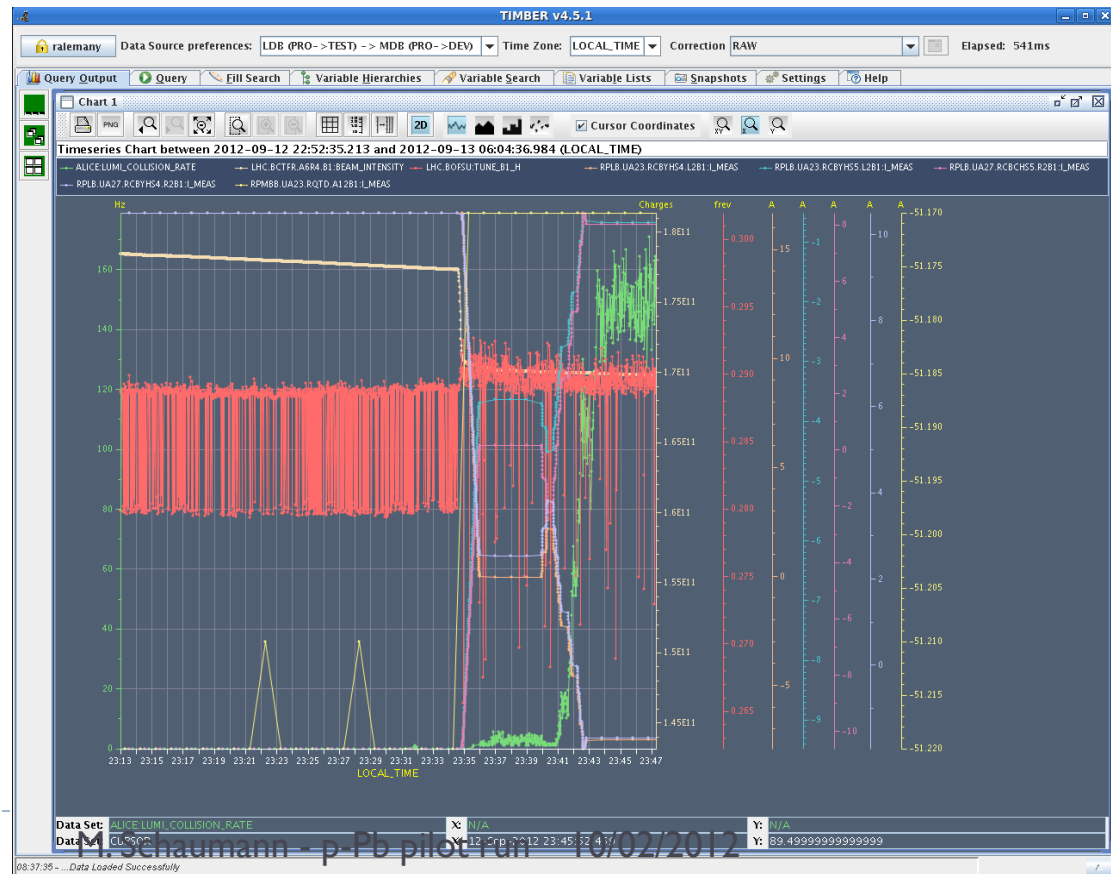
Emittance Evolution



- ▶ The black dots are the energy variation (in arbitrary units)
- ▶ Thick red bunch is non-colliding
- ▶ Same behaviour as the other colliding bunches
- ▶ Emittance growth:
 - ▶ Ions in both planes by approx. the same amount
 - ▶ Protons only horizontal growth

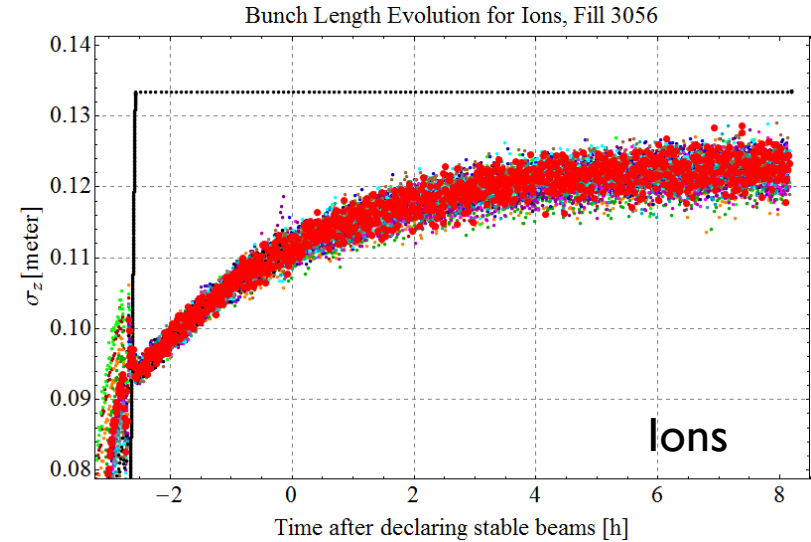
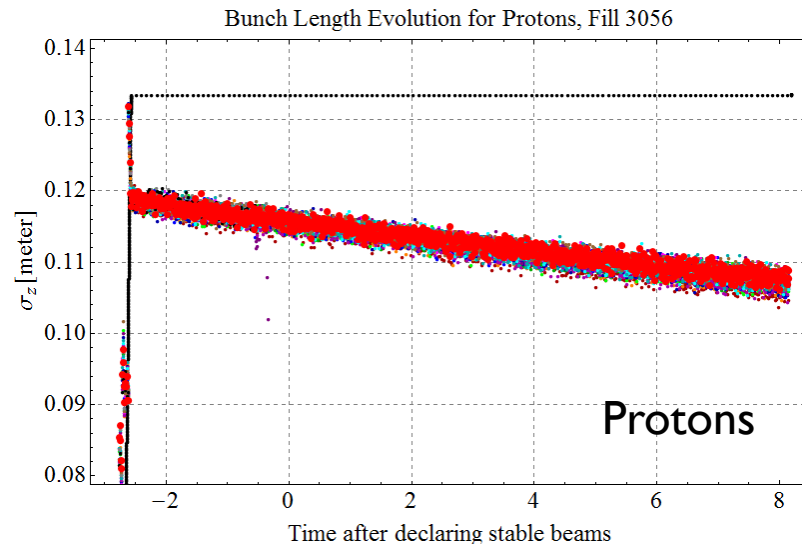
What happened when ALICE was brought into collisions?

- ▶ At the moment the beams started to collide in ALICE:
 - ▶ B1 suddenly loses intensity
 - ▶ B2 horizontal emittance decreases & vertical emittance increases
- ▶ **ALL bunches are affected - also non-colliding ones!**
- ▶ Since the non-colliding bunches are also affected, a beam-beam effect is unlikely
- ▶ Connected with tune change from injection to collision tunes



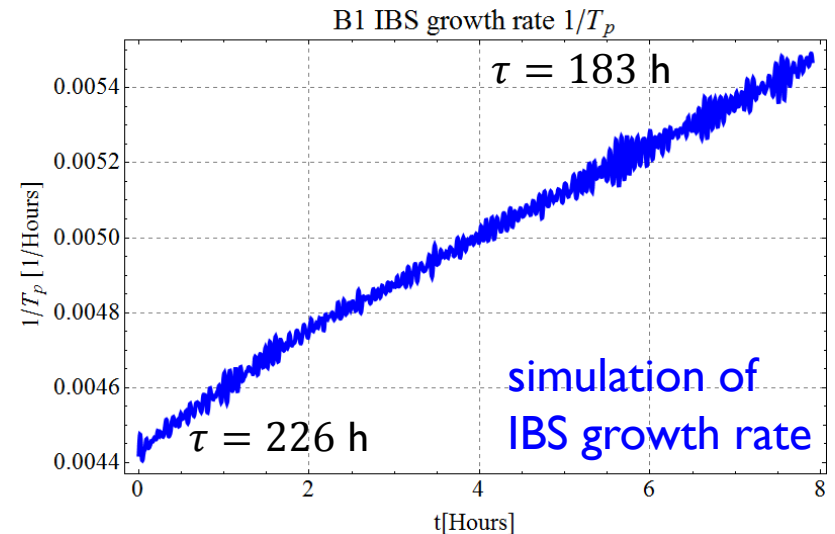
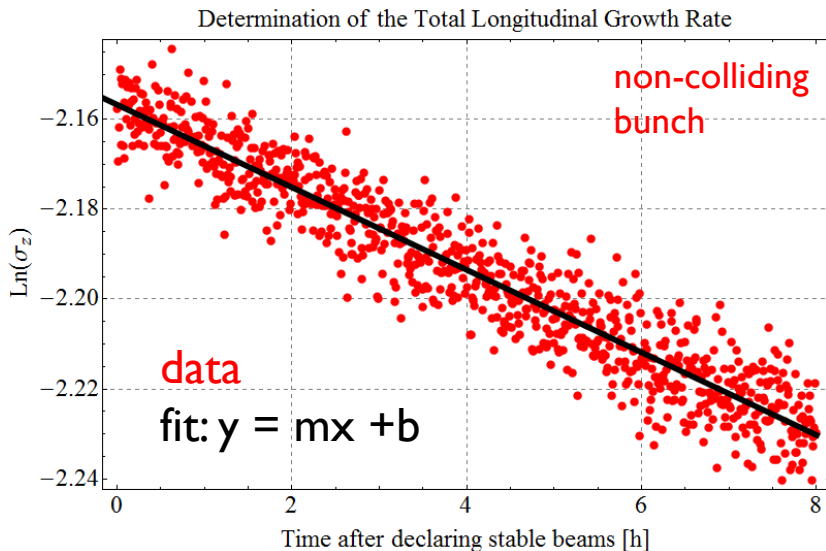
Bunch Length

- ▶ All bunches have the same bunch length
- ▶ Ions clearly show effect of IBS
- ▶ Bunch length is increasing fast after arriving at flattop
- ▶ Length saturates around 12cm



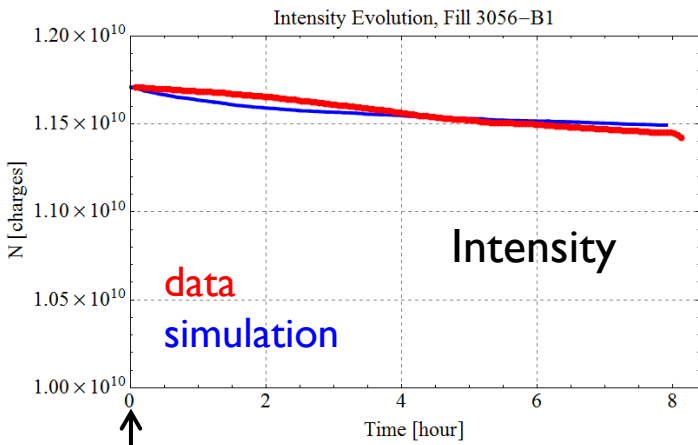
- ▶ Proton bunch length is decreasing
- ▶ IBS is small due to low intensity
- ▶ Radiation Damping becomes visible

Measurement of the Radiation Damping Time for the Proton Beam

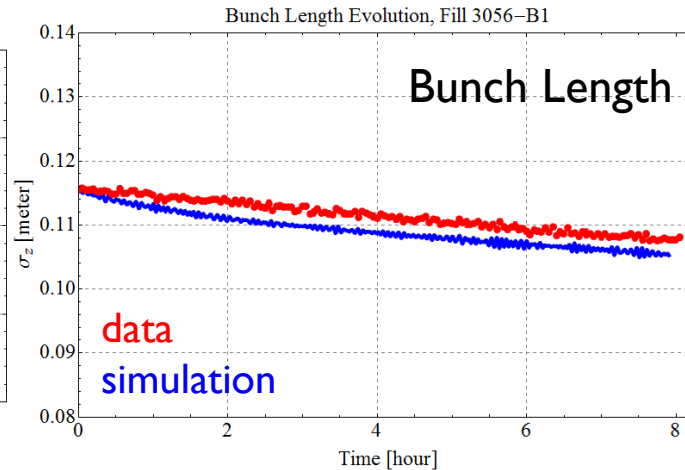


- ▶ Exponential growth: $\sigma_z(t) = a \exp[t/\tau]$
- ▶ Perform linear Fit: $\ln(\sigma_z(t)) = \ln a + t/\tau$
- ▶ Result: $\tau_{tot,meas} = (-108.79 \pm 0.82) \text{ h}$
- ▶ CTE Simulation gives for emittance growth times: $\tau_{IBS} = \{226; 183\} \text{ h}$
 $\tau_{rad} = -69 \text{ h}$ (should be 67.7 h)
- ▶ $\tau_{tot,calc} = 2 \times \left(\frac{1}{\tau_{IBS}} + \frac{1}{\tau_{rad}}\right)^{-1} = \{-199; -222\} \text{ h}$

Simulations of the non-colliding Bunch Protons



start of stable beams

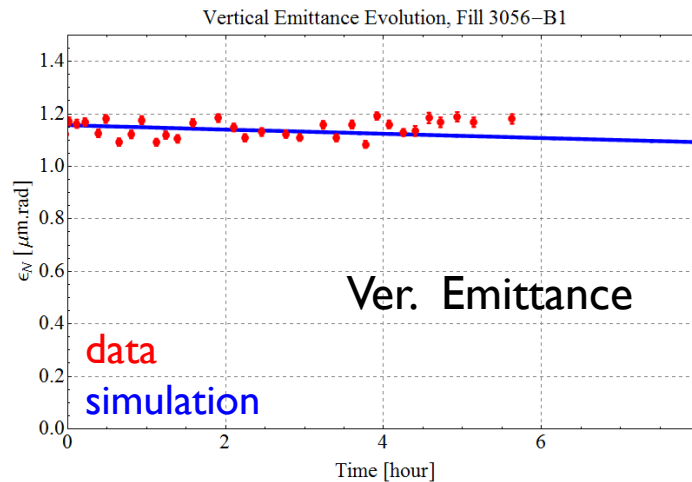
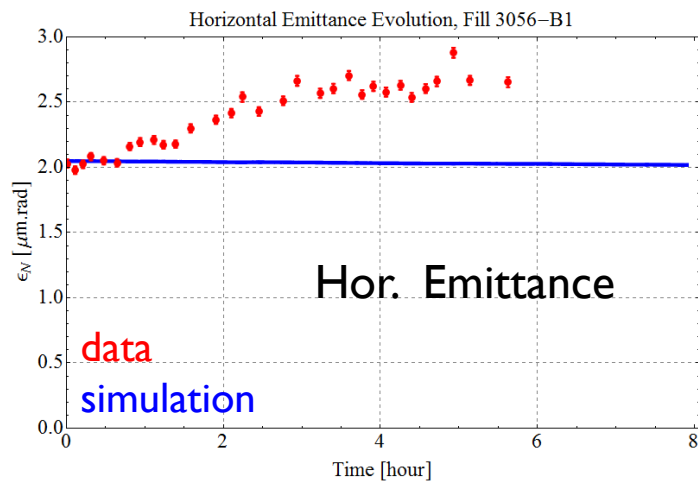


▶ Simulated intensity, bunch length and vertical emittance growth fit well to the data

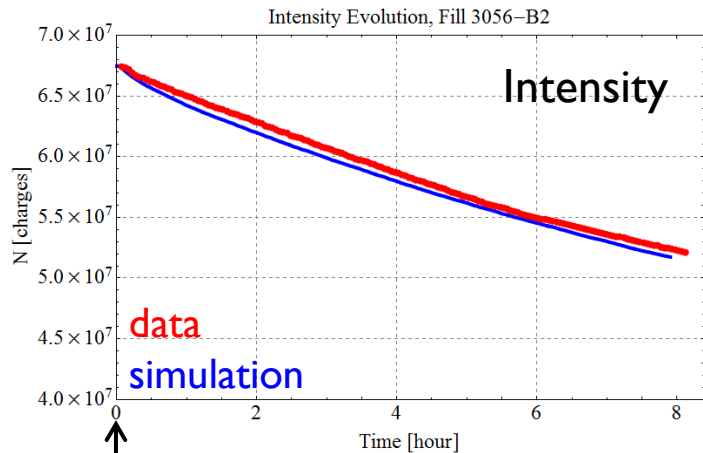
▶ Strong horizontal emittance growth

▶ can not be explained by IBS

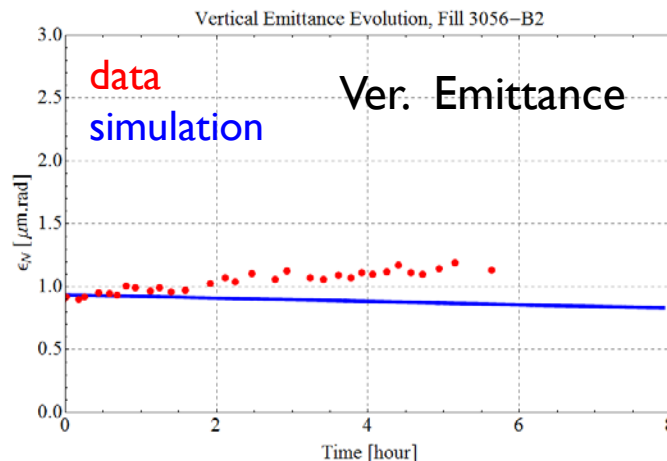
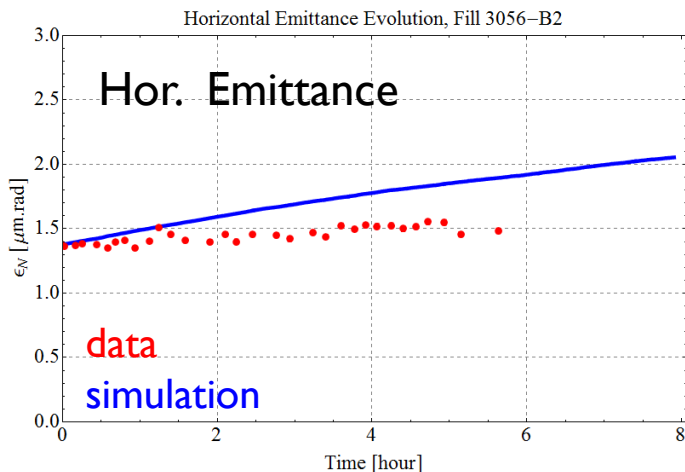
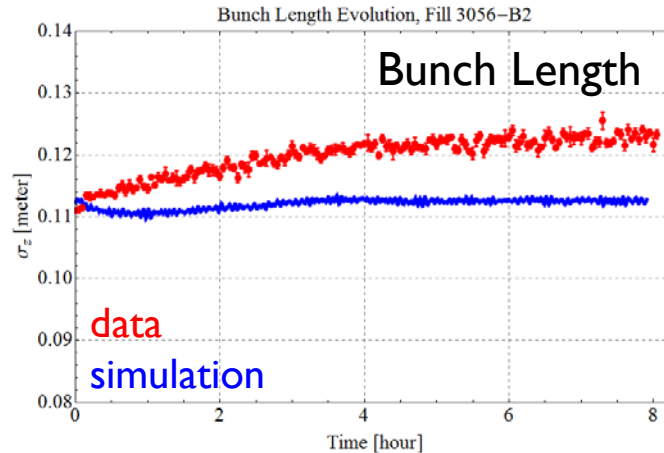
▶ source unknown



Simulations of the non-colliding Bunch Ions



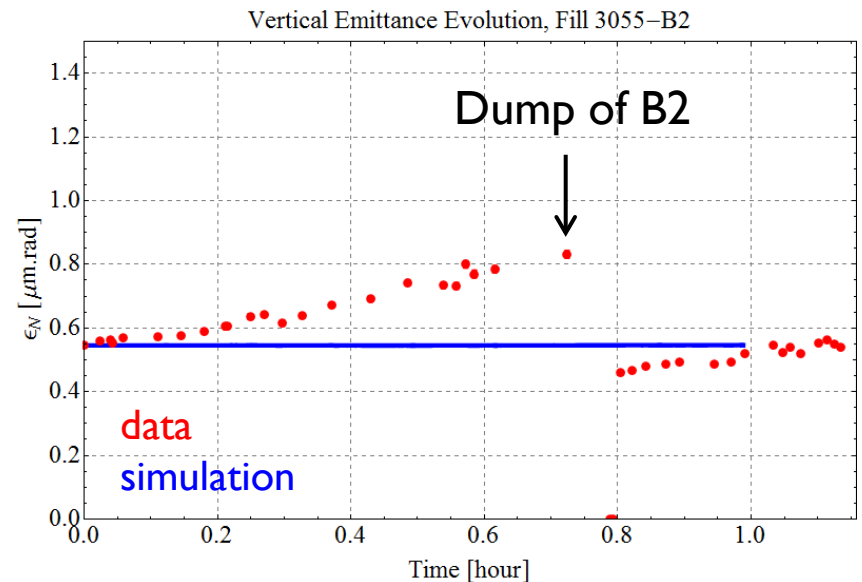
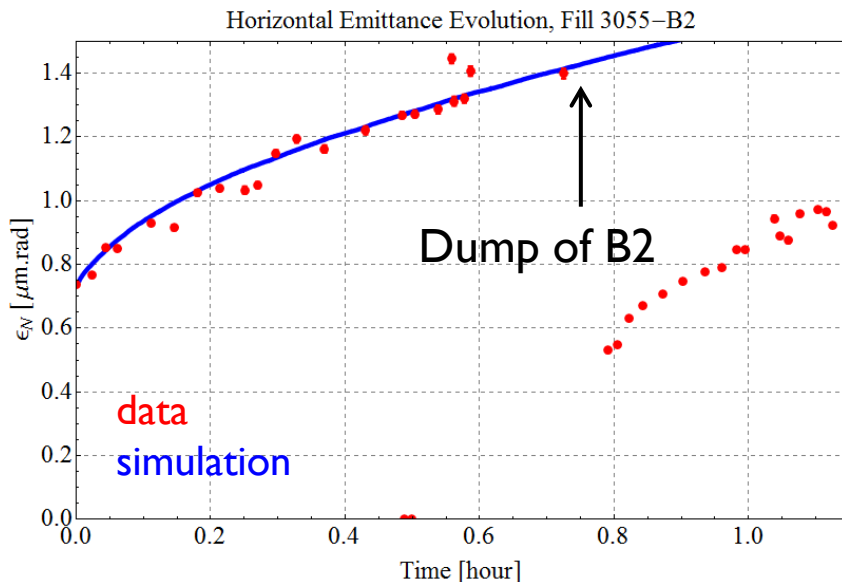
↑
start of stable beams



- ▶ Simulated intensity fits well to the data
- ▶ Bunch length shows different behaviour
 - ▶ underestimated by simulation
- ▶ Therefore, horizontal emittance growth overestimated
- ▶ Vertical emittance growth may be coupling of horizontal IBS into vertical

IBS Simulations at Injection - Ions

- ▶ Pb vertical emittance growth already visible at injection
- ▶ At 450GeV bunch length and horizontal emittance growth fits well with simulation
- ▶ But vertical emittance growth is too fast for IBS



Conclusion

- ▶ No beam-beam effect due to collisions visible in intensity, bunch length or emittance evolution when comparing colliding and non-colliding bunches
 - ▶ all bunches behave similarly
 - ▶ Change to collision tunes caused sudden proton intensity losses and emittance growth of the lead
- ▶ Radiation damping becomes visible in the longitudinal plane for the low intensity protons
 - ▶ observed damping rate not yet in agreement with the calculation
- ▶ Unexplained emittance growth in horizontal plane of the p-beam and vertical plane of the Pb-beam – too strong for IBS
- ▶ Pb vertical emittance growth also visible at injection
- ▶ Emittance calibration rely on wire scanner data - but we observed some discrepancies when comparing the relative evolution with the BGI and BSRT