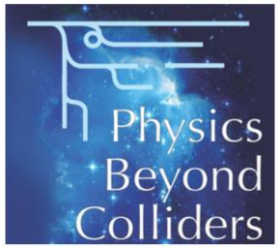
MD-3284:
Partially Stripped Ions in LHC

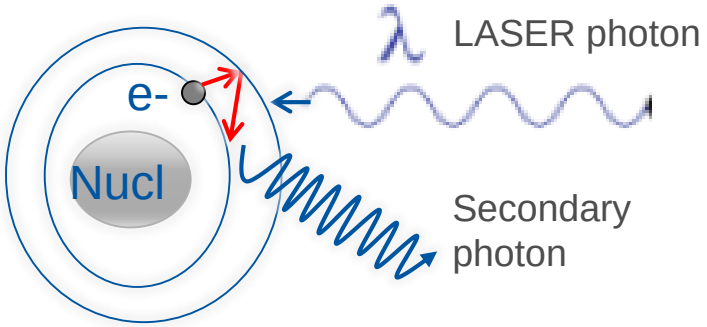
M. Schaumann, A. Abramov, R. Alemany Fernandez, T. Argyropoulos, H. Bartosik, N. Biancacci, T. Bohl, R. Bruce, K. Cornelis, N. Fuster Martinez, R. Giachino, G.H. Hemelsoet, S. Hirlaender, M. Jebramcik, J.M. Jowett, V. Kain, M.W. Krasny, J. Molson, G. Papotti, M. Solfaroli Camillocci, H. Timko, D. Valuch, J. Wenninger

Background and Motivation

- The **Gamma Factory** initiative proposes to use **partially stripped ion (PSI)** beams as drivers of a new type, high intensity photon source.
- The Gamma Factory proposal is part of the ongoing **Physics Beyond Collider studies**.
- Initial beam tests with PSI beams have been executed in the SPS in 2017/18.
- Storing PSI in LHC at 6.5TeV is the **1st of 5 milestones** of the Gamma Factory.



The Idea of a Gamma Factory



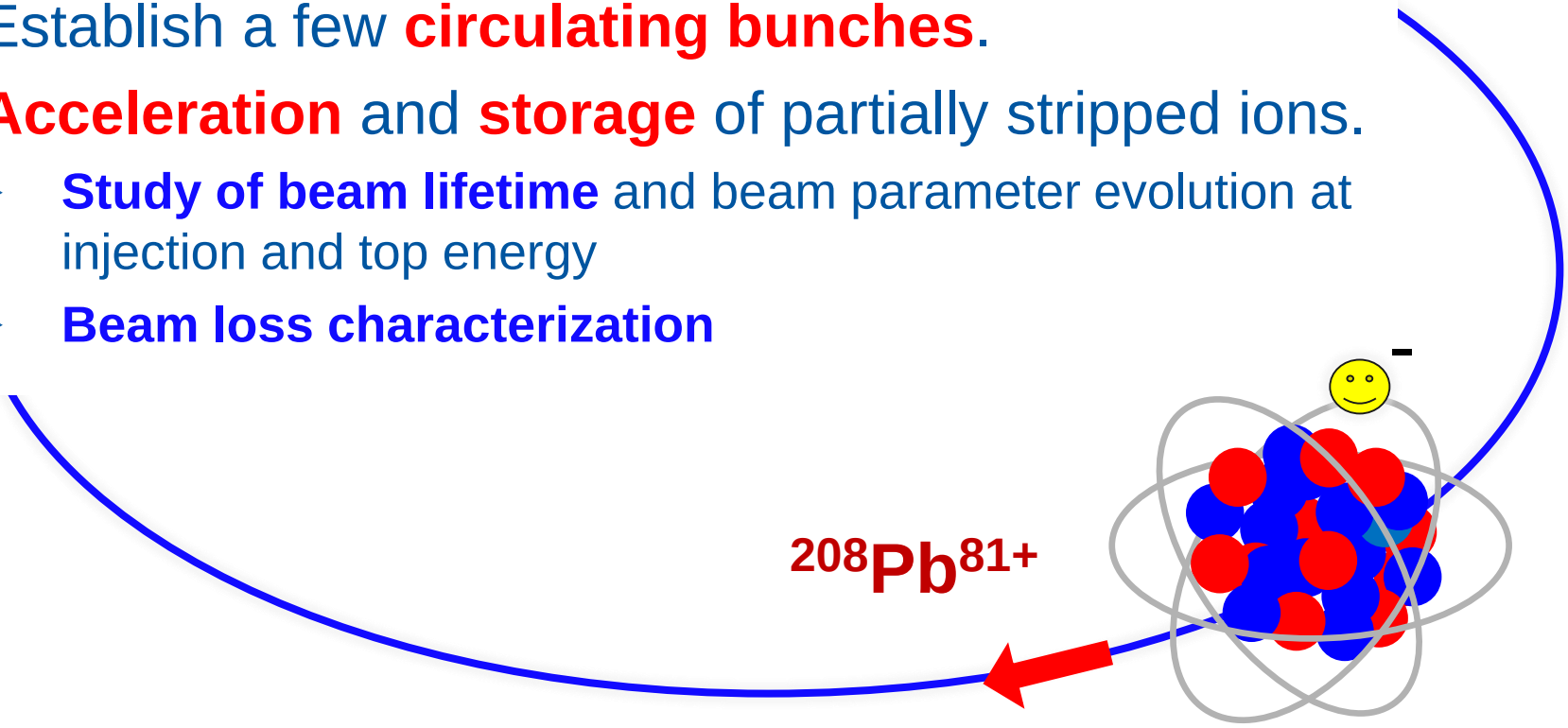
1.) Resonant absorption of the laser photons by the Partially Stripped Ion (PSI) beam.

2.) Followed by a spontaneous atomic-transition emissions of secondary photons.

LASER photon strongly boosted by $(2\gamma_{rel})^2$ → For LHC energy, photon energy exceeds those reachable for FEL at high light intensity.

Goals of this initial MD in the LHC

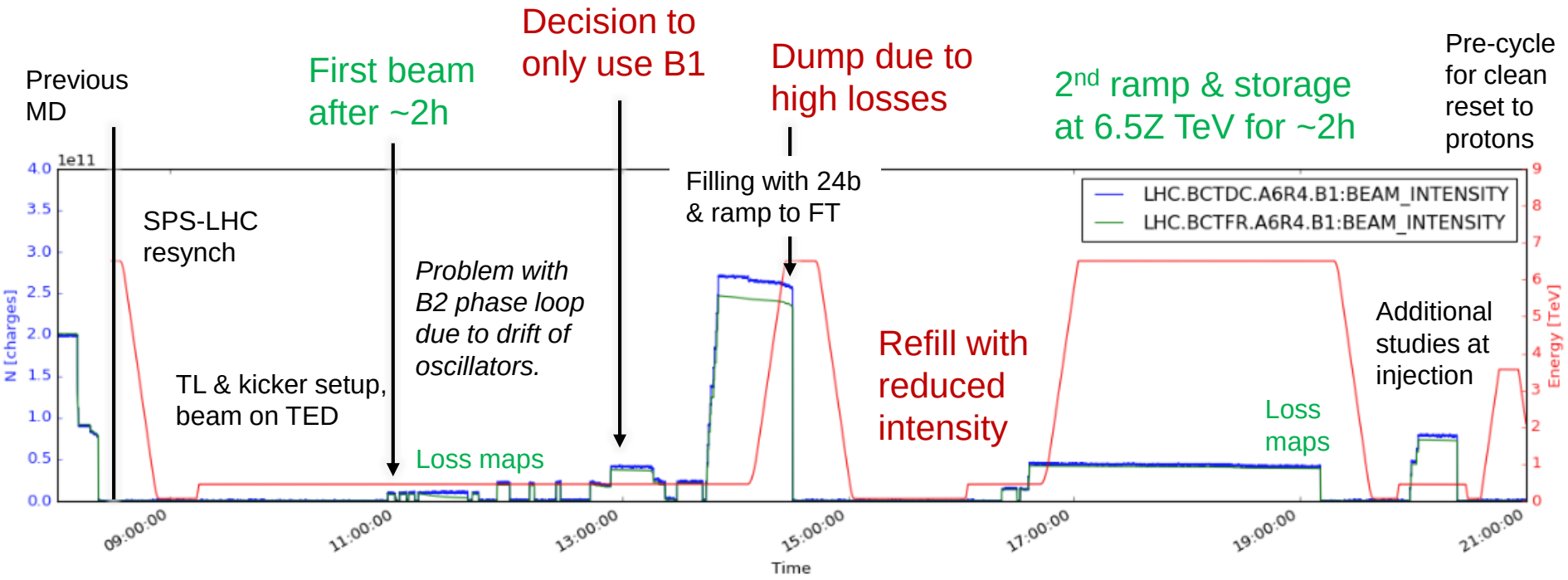
- **Inject** new particle “species” in the LHC
  - Well-known Pb-208, but with one remaining electron
- Establish a few **circulating bunches**.
- **Acceleration** and **storage** of partially stripped ions.
  - **Study of beam lifetime** and beam parameter evolution at injection and top energy
  - **Beam loss characterization**



MD Setup

- **LHC nominal cycle** until **flat top** (no squeeze, no collisions)
- **Usual injection setup for ions:**
  - particle type, transfer lines, kickers, SPS-LHC resynch & RF (lower RF-frequency than Pb^{82+})
- **Beam**:
  - Duplets with 2 bunches spaced by 200ns and total intensity of >2e10 charges.
  - Pilot scraping in the SPS to get below 1e10 for initial injections.
- **Total circulating intensity**: **<3e11** (SETUP beam)

Evolution of the MD

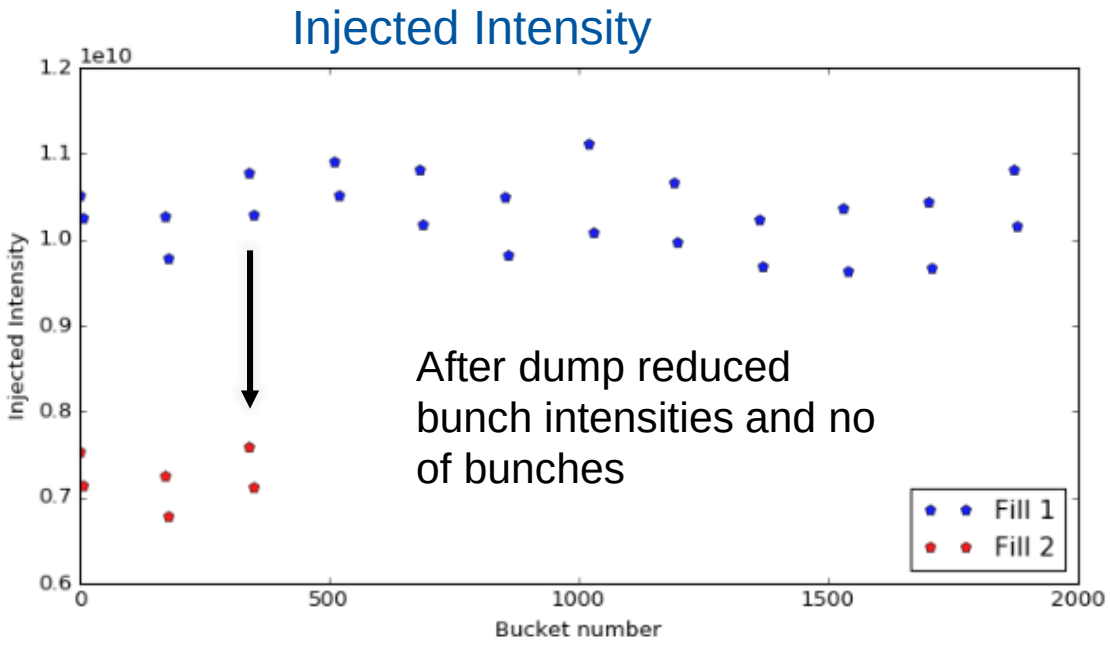


Decision to only use B1.
B2 not strictly necessary for the success of the MD, no collisions were foreseen.

Dump due to high losses 11R7.
Bad collimation efficiency and instability (zero octupoles and no damper).

Refill
Set octupoles during ramp, reduce number of bunches & bunch intensity.

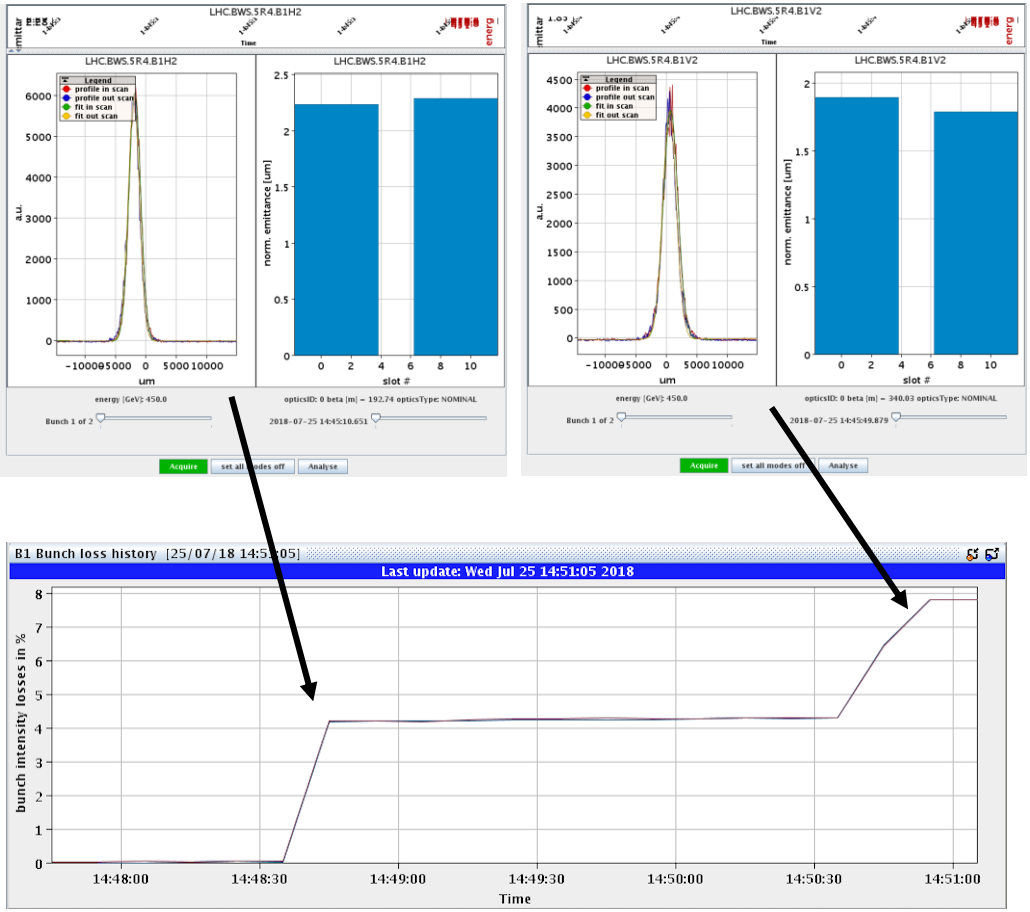
Beam Quality – Injected Intensity



Fill 1:
- 1.1E10 charges/bunch
- 24 bunches

Fill 2 (reduced intensity):
- 0.75E10 charges/bunch (scraping in SPS)
- 6 bunches

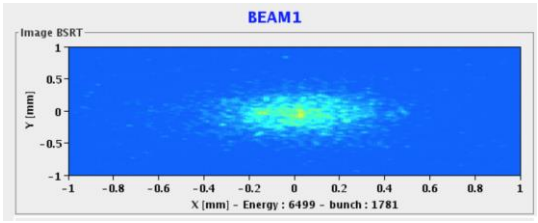
Beam Quality - Emittances



Emittances could not be measured well.

BSRT:

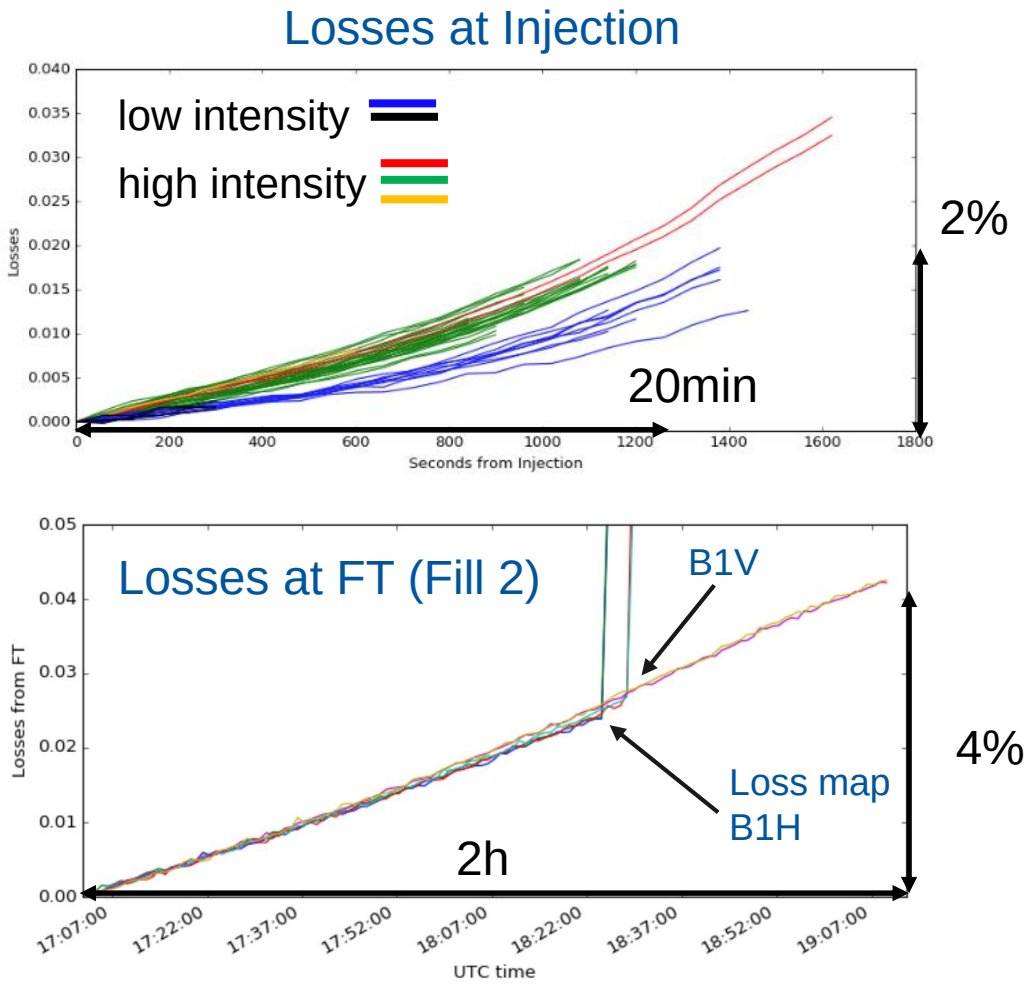
- No light at injection
- Not always acquiring at FT (2nd fill)



WS:

- ~4% intensity loss per scan by stripping of e-,
- not used at FT

Beam Lifetime



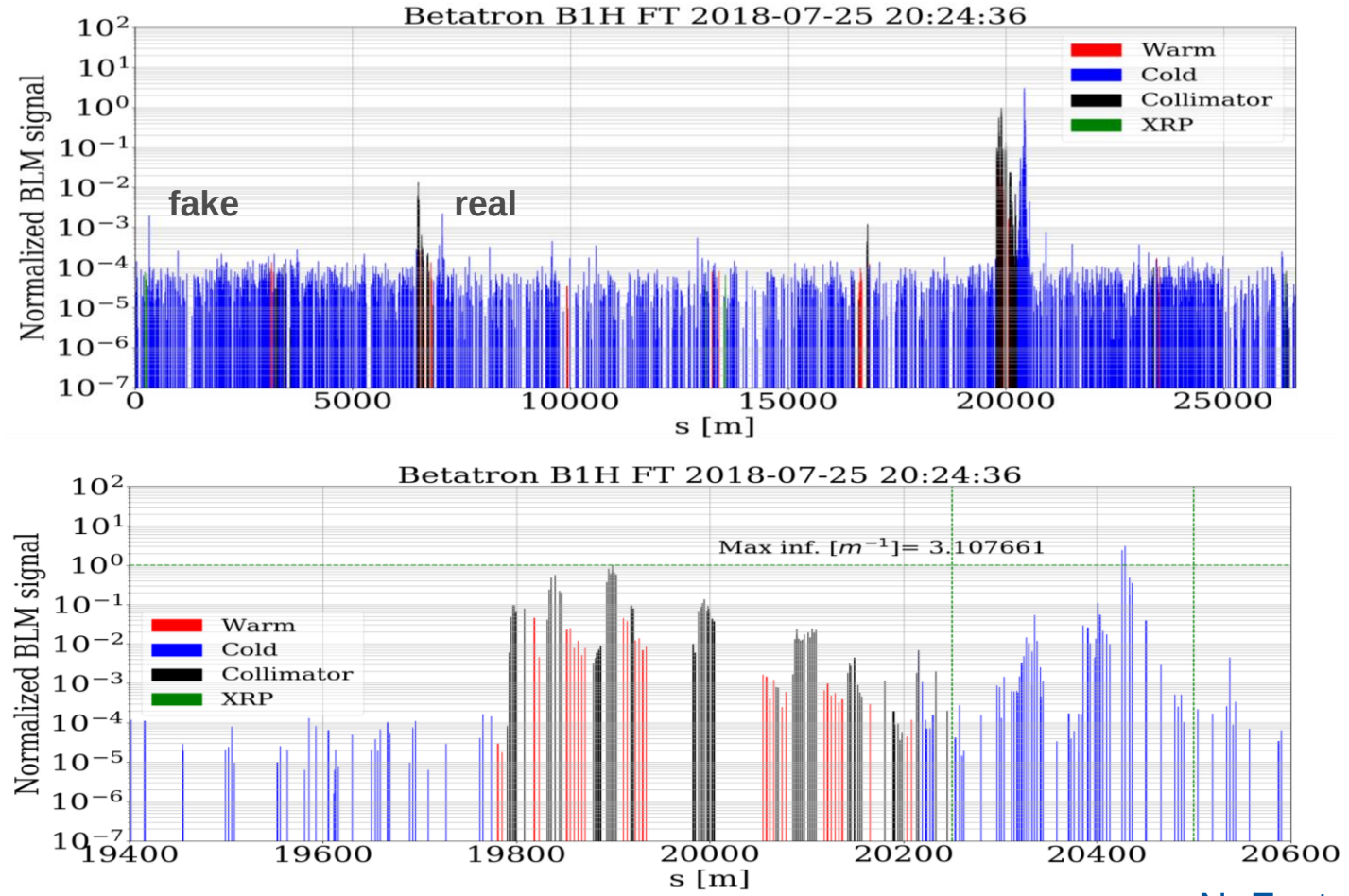
Lifetimes (fitted):

Injection: ~10h

FT: ~40h

This exceeded the expectations extrapolated from SPS MD results.

Loss map – B1H at Flat top

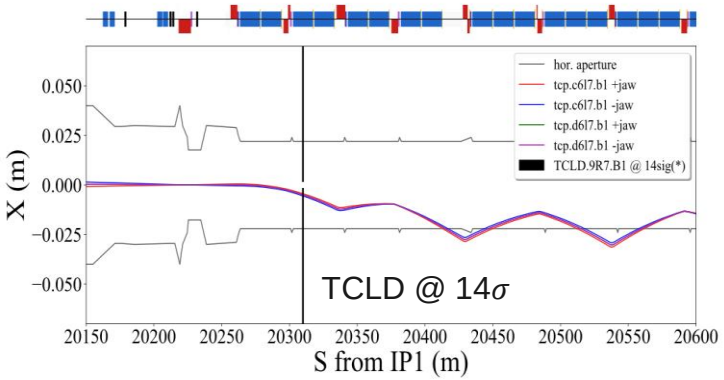


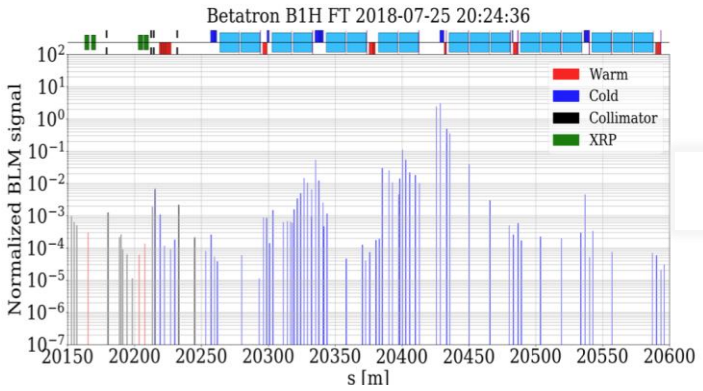
N. Fuster Martinez

A. Abramov, R. Bruce, N. Fuster Martinez

Collimation

- **Worst collimation efficiency ever observed**.
  - → **limits intensity** that can be ramped reliably without spurious dumps.
  - → Lead to dump of fill 1 after small instability (no octupoles and no dampers).
- Very high **stripping probability of remaining electron** during passage through primary collimator.
  - → Fully stripped ions (Pb82+) scatter back in beam, but have **large magnetic rigidity offset** from main beam.
  - → Pb82+ follow locally generated dispersion and get **lost on aperture in cell 11**





- Foreseen momentum loss map was not done, because of the high losses in cell 11R7 we had a concerns that could induce a quench.
- Future alleviation under study: DS collimators, crystal collimation

Summary and Outlook

- On 25 July 2018 the **LHC injected, accelerated** and **stored** lead ions with one remaining electron (**208Pb81+**) for the first time.

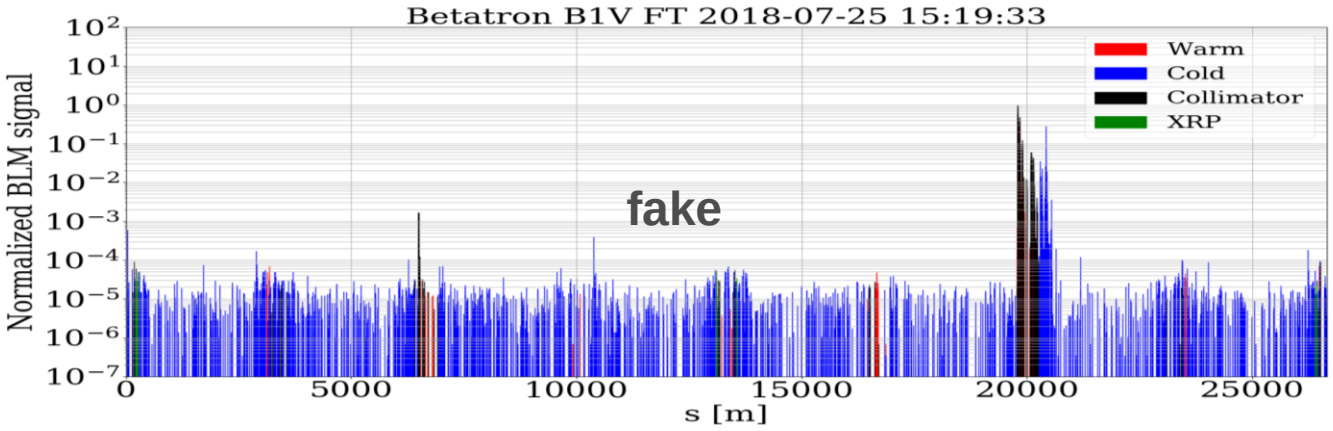
  → Achieving the 1st milestone of the Gamma Factory

- A few Pb81+ bunches circulated at 6.5 TeV proton equivalent energy with **beam lifetimes of about 40 hours**.
- A **dominant limit** of the beam intensity is the **collimation efficiency**.

- **Crystal collimation** MD with PSI beams was requested to study its mitigation potential **to overcome the collimation limit**.
  - Scheduled for MD4, but was canceled just before the start due to unavailability of ion beams.

Extra Slides

Loss Map– B1V Flat top



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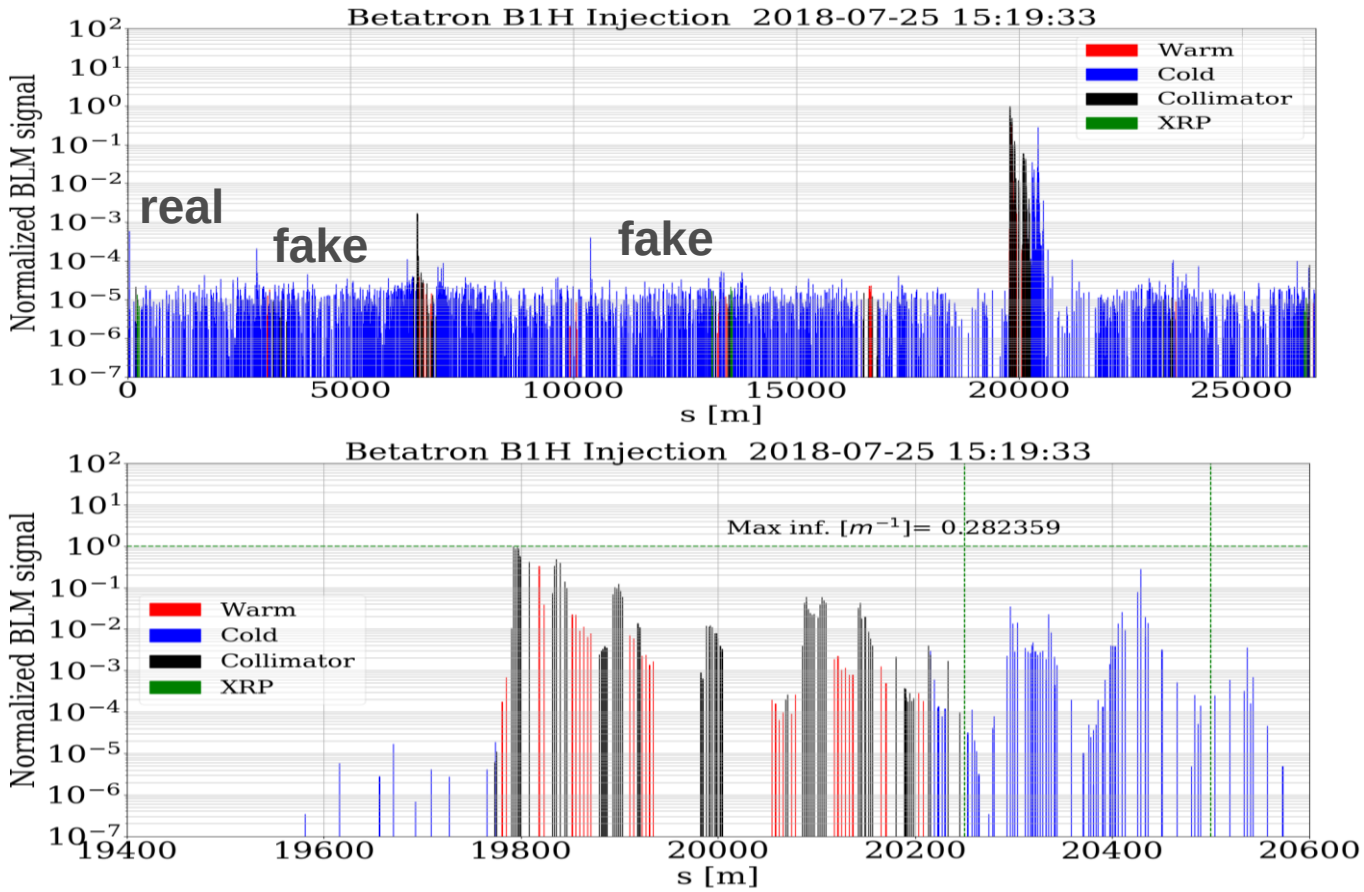
Loss Map – B1H Injection



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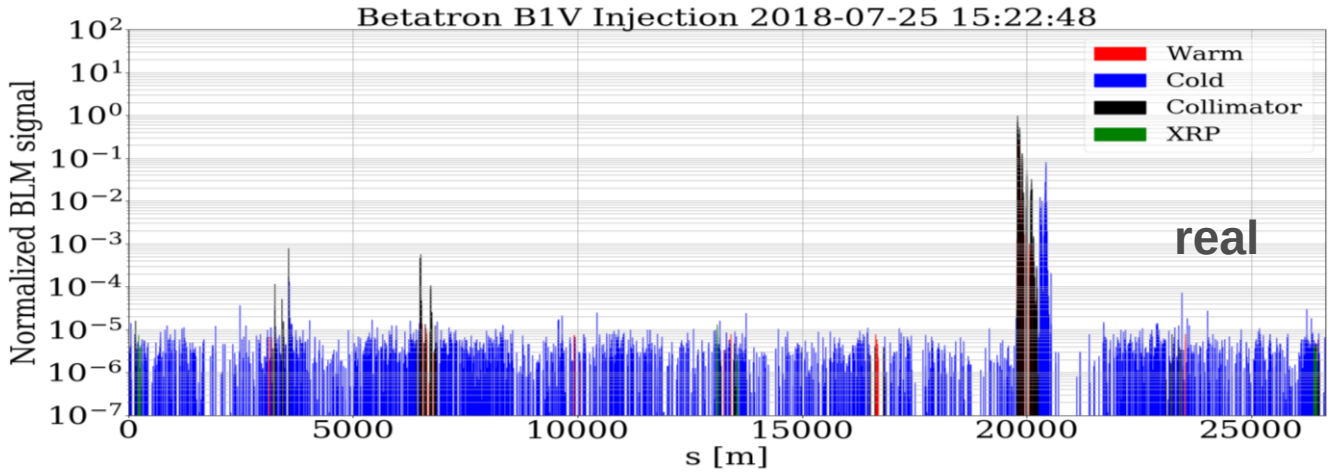
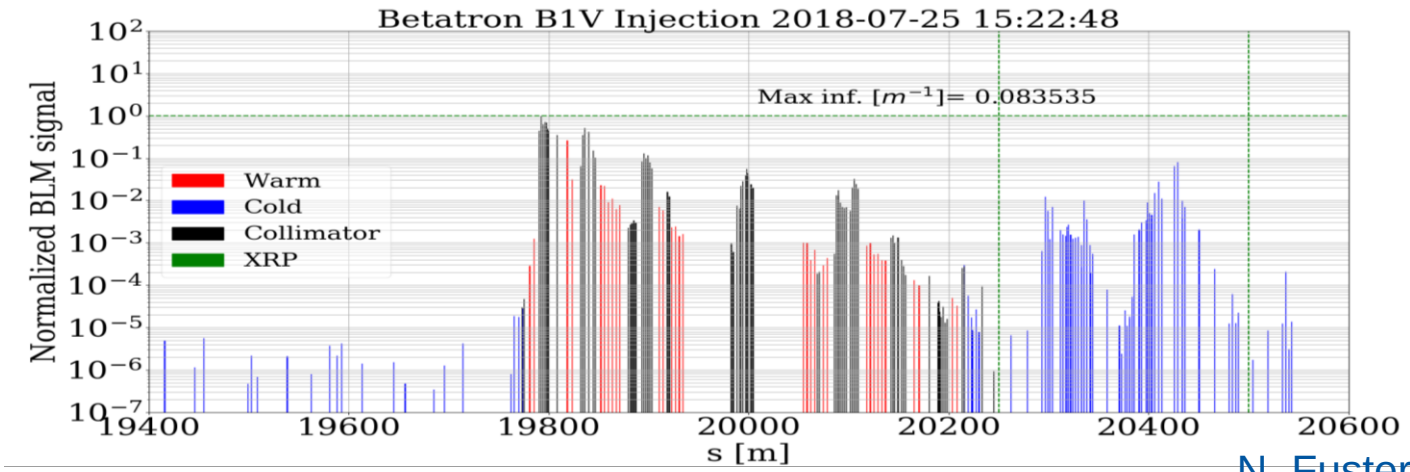
Loss Map – B1V Injection





N. Fuster Martinez