Funded by the Horizon 2020
Framework Programme of the
European Union

# WP3 Accumulator

## Transfer line, Accumulator and Beam Switchyard

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ESSnuSB/EuroNuNet meeting in Zagreb, October 21-24, 2019

EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

# WP3 Objectives

- Study the accumulator operation scheme
- Design of the accumulator ring, its transfer line and its extraction kicker
- Study the stripping of $H^-$
- Design of the ejection switchyard.

# Purpose of the accumulator


- Collect beam particles from the ESS linac over many turns.
- Extract over a single turn.
- Transform 2.86 ms long pulses from the linac to ~1.5 μs short, highly compressed pulses in order to meet the target station requirements

# Design Goals and Constraints

Low level of particle loss! <1 W/m uncontrolled beam loss

- **Ring:**
  - Circumference: short enough pulse, fit into ESS ~ 400 m
  - Charge exchange injection!
  - Space charge forces and resonances
  - Large aperture
  - Radiofrequency cavities to maintain extraction gap
  - Limit the beam storing time
- **Transfer line:**
  - Lower limit on radius enforced by Lorentz stripping
  - Upper limit, ESS site restrictions (target building!)
- **Switchyard**
  - Fast switching to distribute the beam power over four targets
  - Space constraints from the overall layout

# Disclaimer

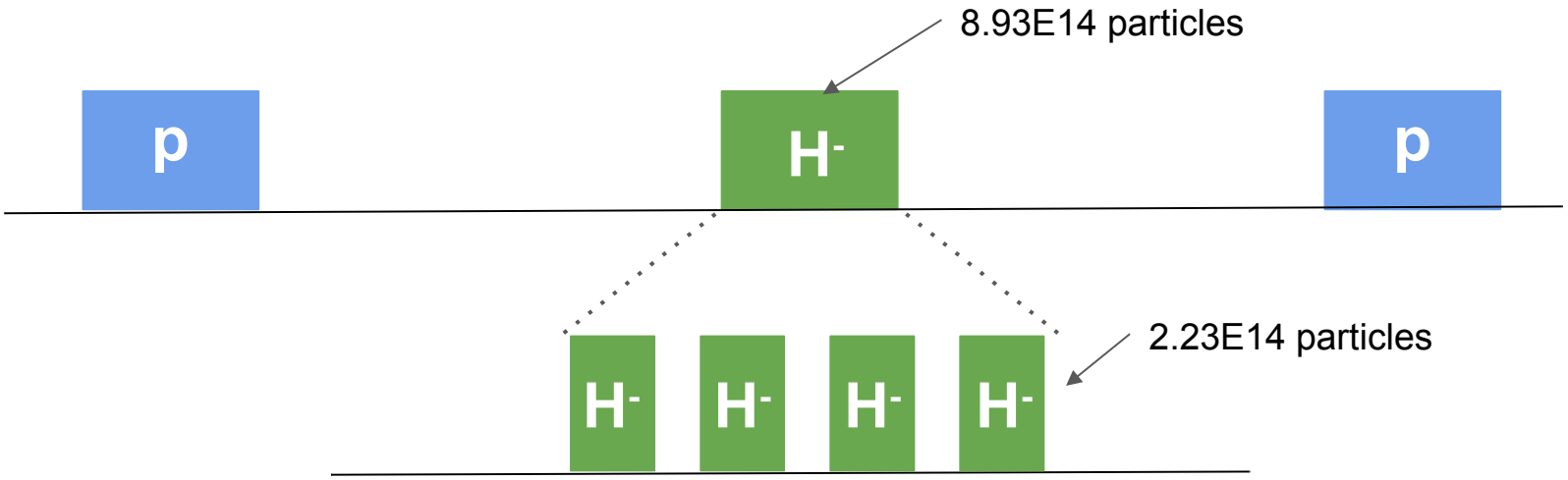
There will be beam loss!

If 5 MW on target is required by experiment performance we need to have more* than 5 MW of beam power in the ESS linac.

* The beam power in the SNS linac is almost 1.6 MW for 1.4 MW beam on target.

# Constraints from both sides

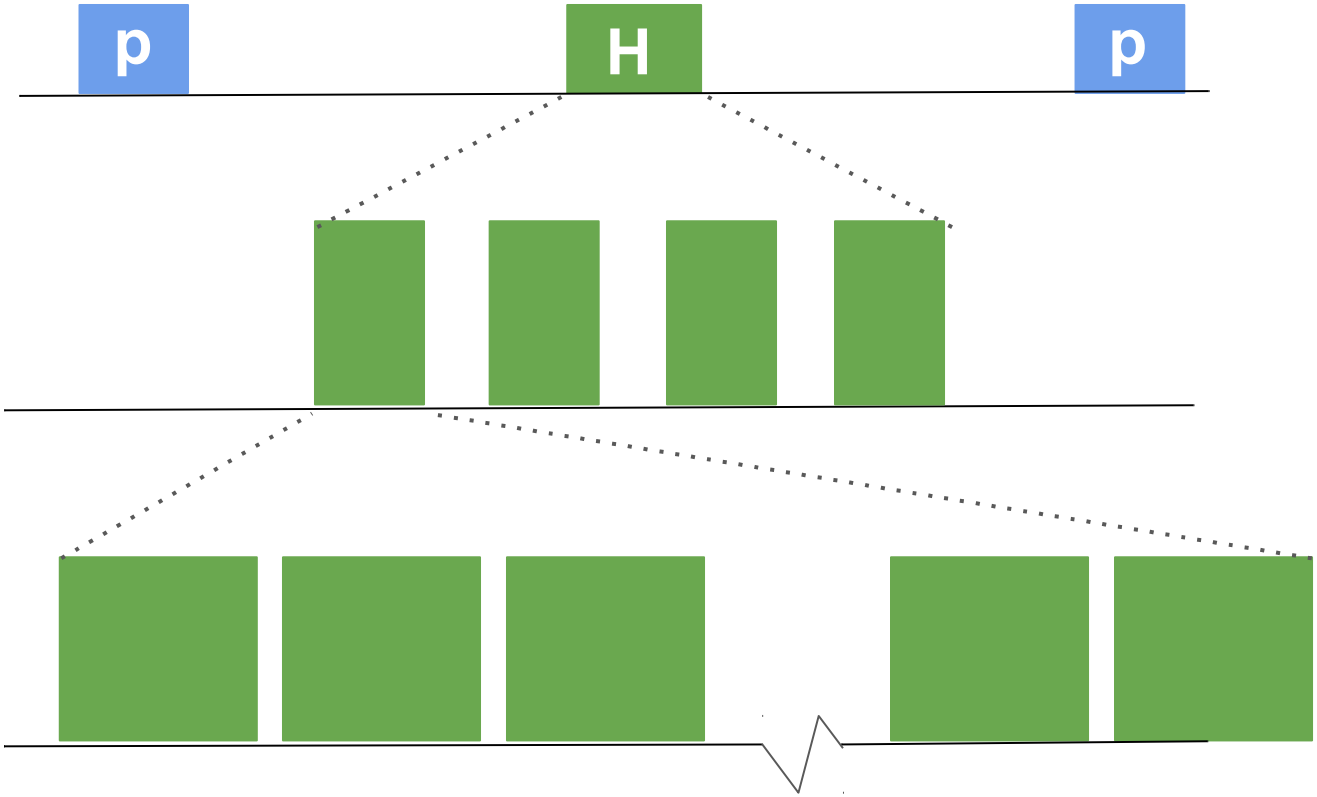
- Linac is pulsed at 28 Hz.
- Maximum power per target is 1.67 MW
  - 1.25 MW in normal operation
  - ➔ Each linac pulse must be split into four sub-pulses, or batches.



# What we need

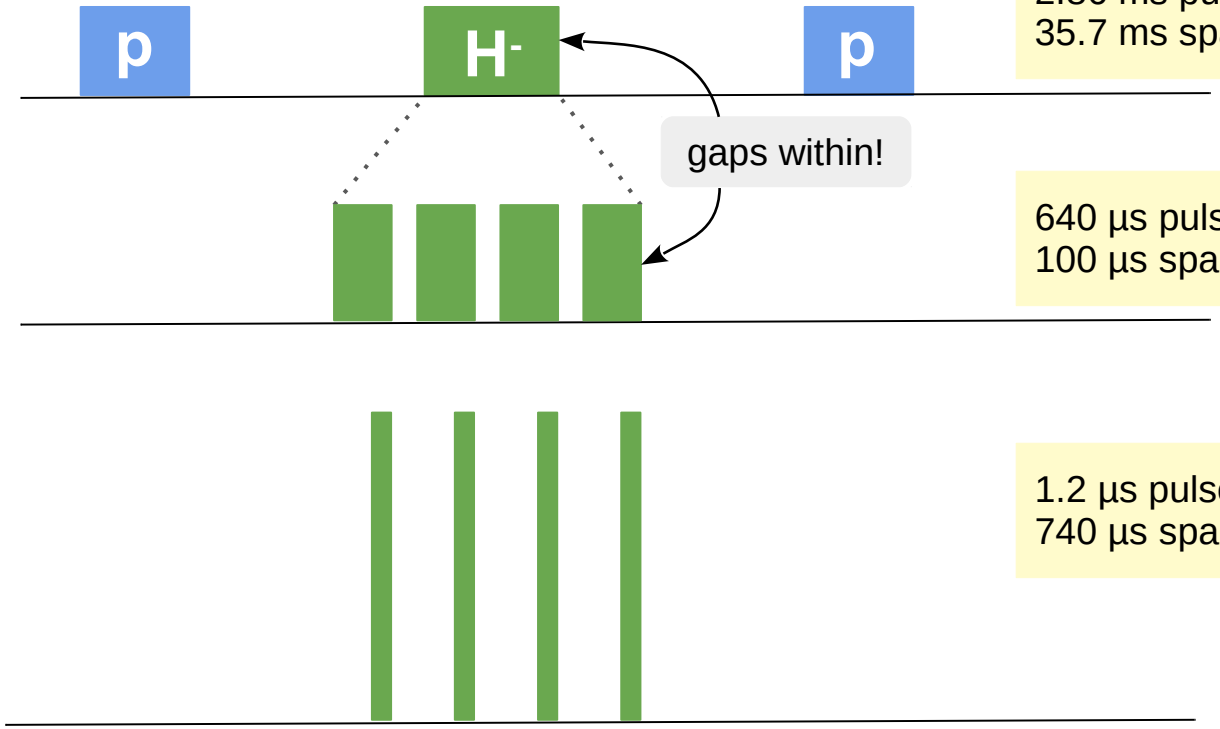
“Injection” gaps
100 μs long,
Three gaps =>
four batches

“Extraction” gaps
133 ns long, every
1.33 μs.



# Pulse structure at different levels

Linac: 28 Hz




Accumulator

Target: 1.35 kHz

# Activities in 2019

- Settle on a baseline
  - Pulsing scheme: Investigate alternatives
  - beam emittance, beam distribution
- Investigate geographical layout
- First Transfer line design
- Tweak the lattice
  - Chromaticity correction
- Optimize the injection
- Study the foil temperature for different configurations, injection procedures
- First discussions on extraction with CERN experts
- Study particle transmission in the switchyard
- Make sure all recommendations of the IAP are met.

# Outcomes of the 1st yearly meeting in Strasbourg

Coordination between WPs

1. Inter-WP incoherence regarding the linac beam energy and current.
2. Improved coordination with WP2 and WP4 needed.
3. Baseline pulsing scheme not compatible with horn PSU. Are there other issues?
4. Create parameter list

Extraction/ Switchyard

5. Simulation from extraction to target should be carried out. Strong focusing might create a halo.
6. Who designs the extraction kickers?
7. Investigate technical challenges of power supply for the switchyard and extraction kicker magnets.

# Outcomes of the 1st yearly meeting in Strasbourg

Ring design, simulations

8. Ensure space for sextupole magnets for chromaticity correction.
9. Investigate the use of barrier RF and no RF cavities.
10. Include *indirect* space charge (mirror) effects in tracking simulations.
11. Foil stripping: Include scattering in the foil.
12. Foil stripping: Continue looking at ways of mitigating foil temperature.

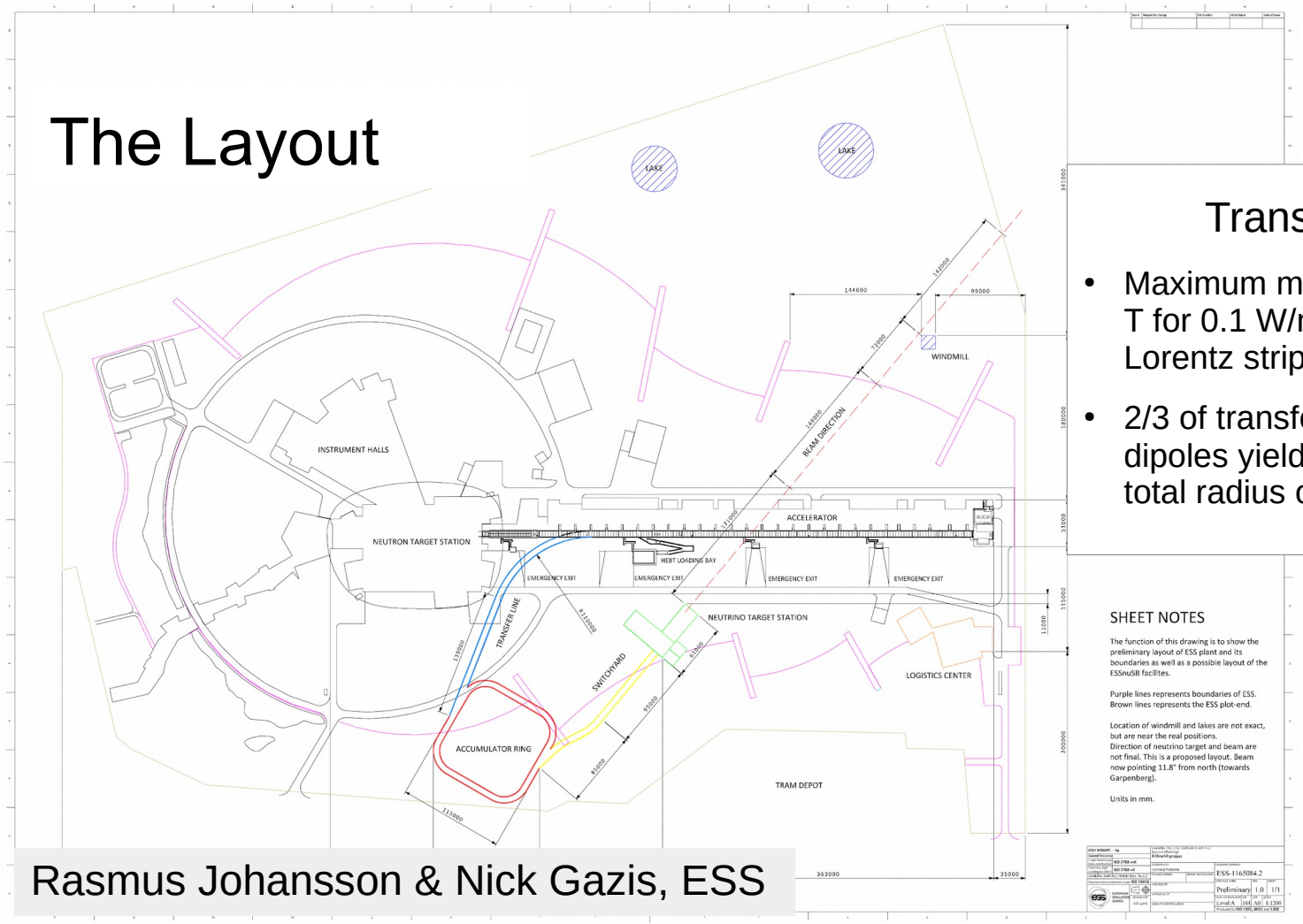
Collimation

13. Collimator acceptance to be set in communication with WP4.
14. Primary collimator and machine acceptance should be set.
15. Investigate “good” location for collimators.

# Where are we now?

- Overall layout and transfer line
- Ring Lattice
- Multiparticle simulations
- Switchyard

# The Layout

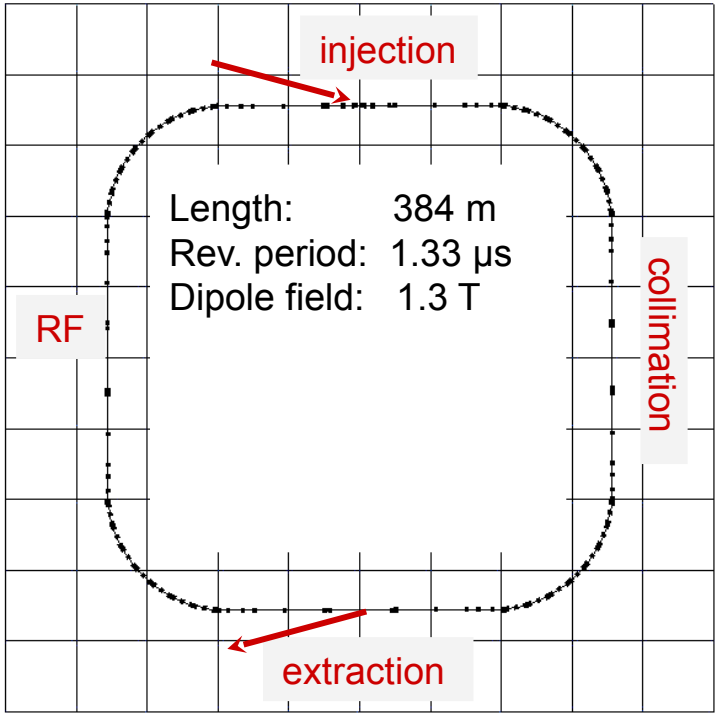


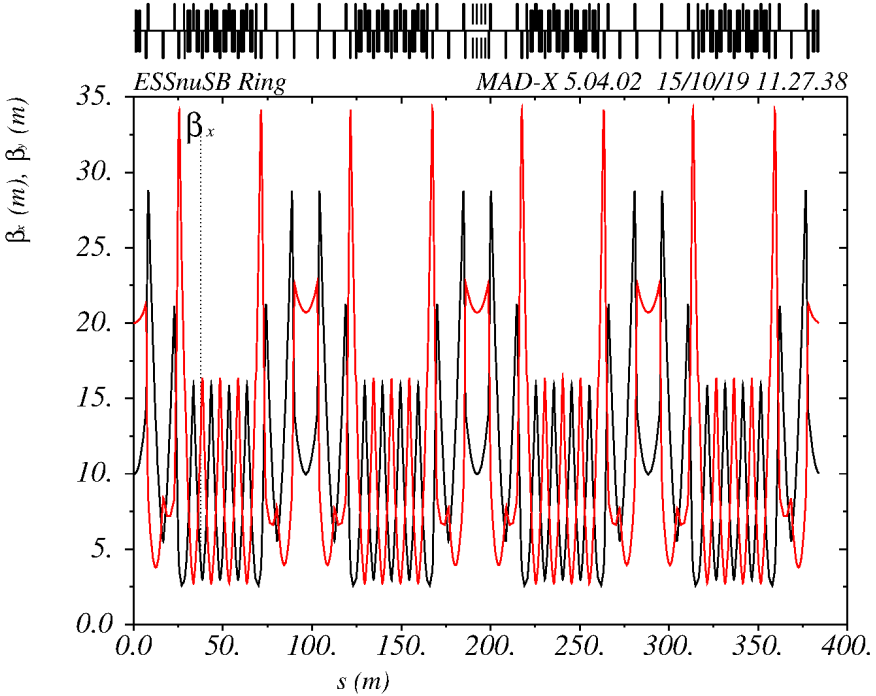

## Transfer line

- Maximum magnetic field 0.15 T for 0.1 W/m loss due to Lorentz stripping.
- 2/3 of transfer line filled with dipoles yields a minimum total radius of 110 m.

Rasmus Johansson & Nick Gazis, ESS

# The Ring Lattice

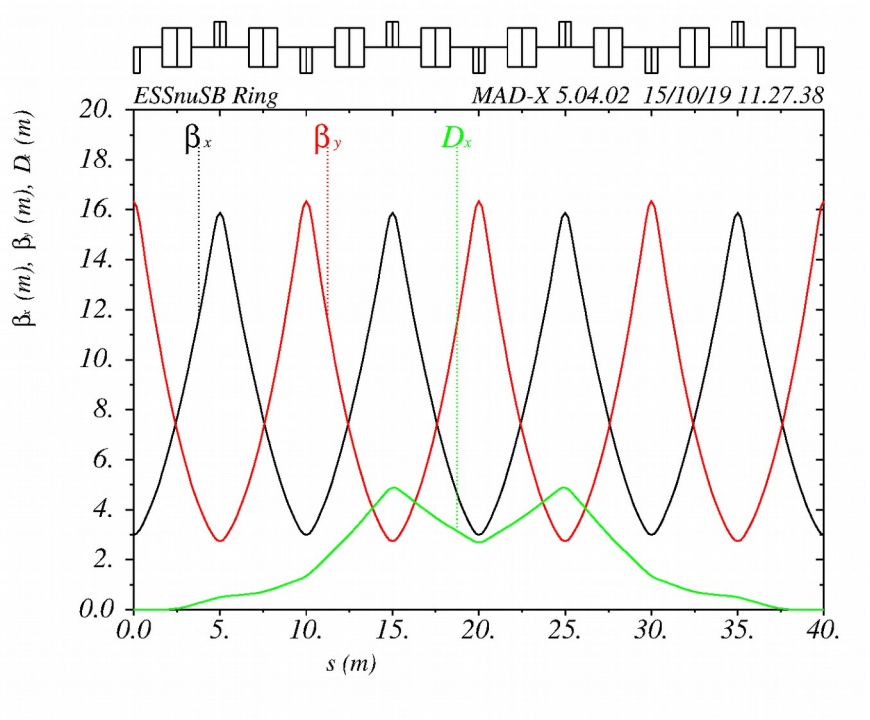


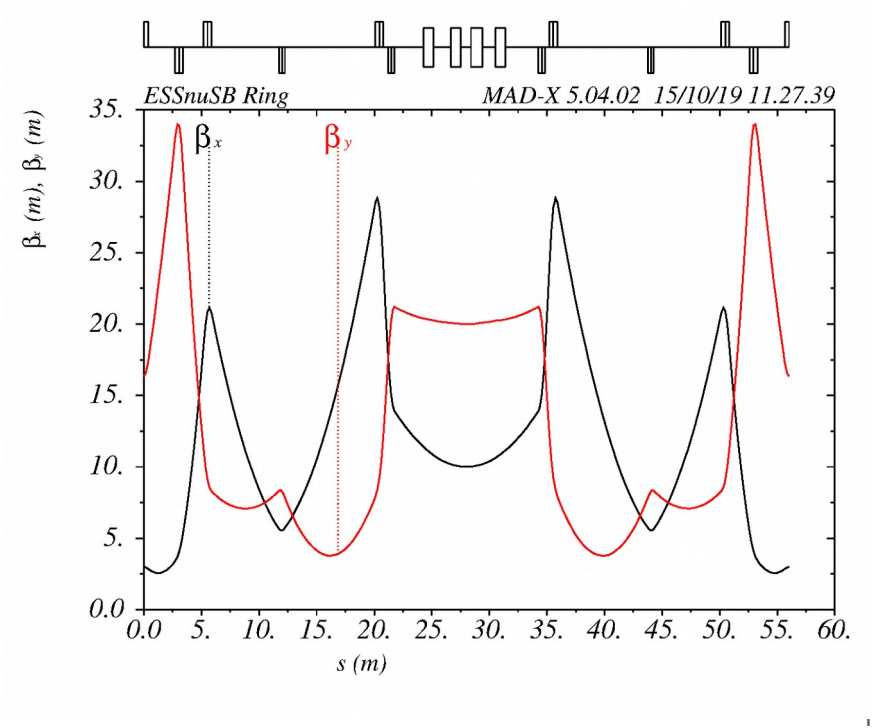

Horst Schönauer, CERN

# The Ring Lattice, more details

## Arc



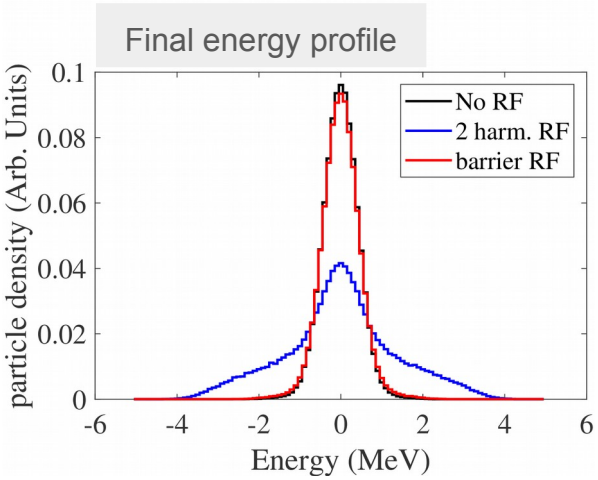

## Injection

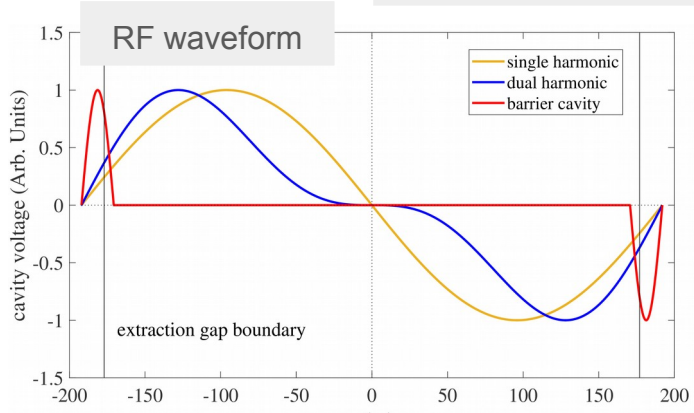


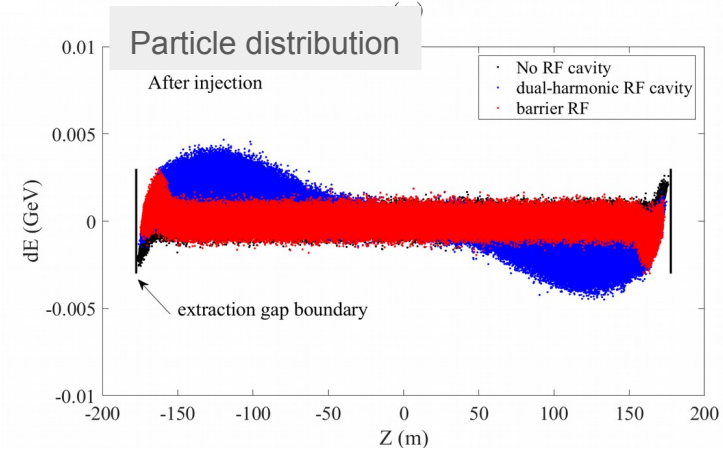
# RF cavities

Ye Zou, Uppsala

- RF cavities used to control longitudinal motion.
- Maintain the extraction gap above 100 ns ≈ 8%* of revolution period
- ...while keeping energy spread moderate.

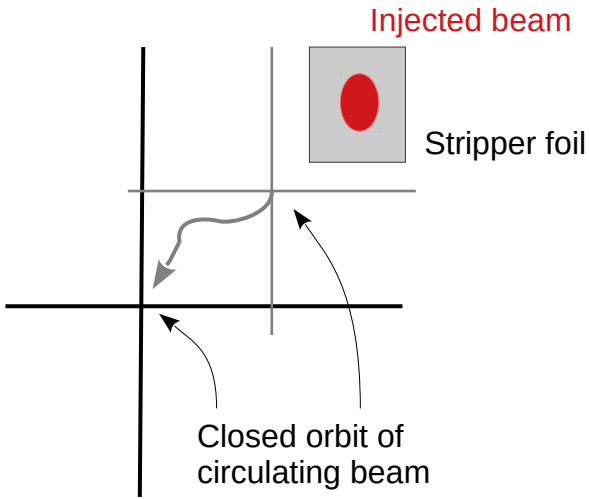


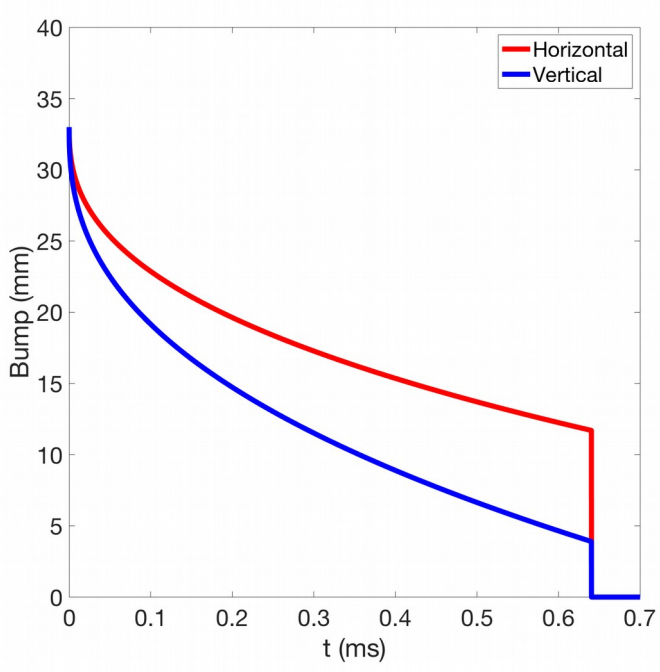




* Note that we assume gaps in the incoming beam corresponding to 10% of the revolution period.

# Injection Painting



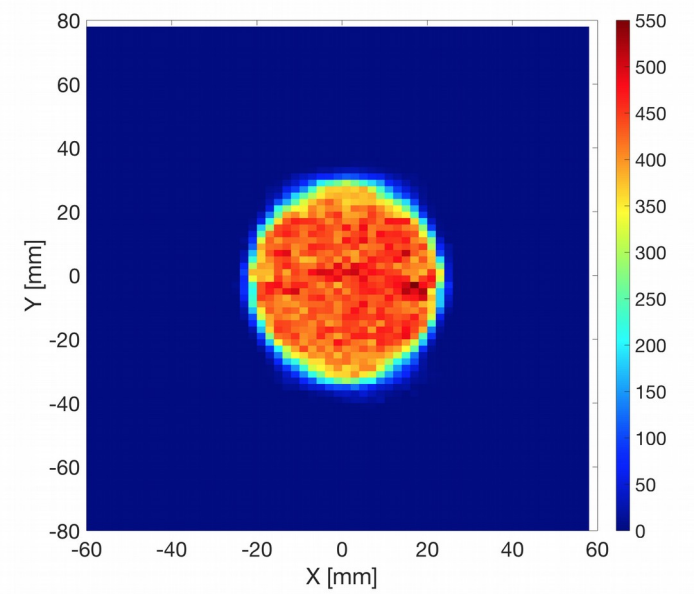

Example: correlated painting bump



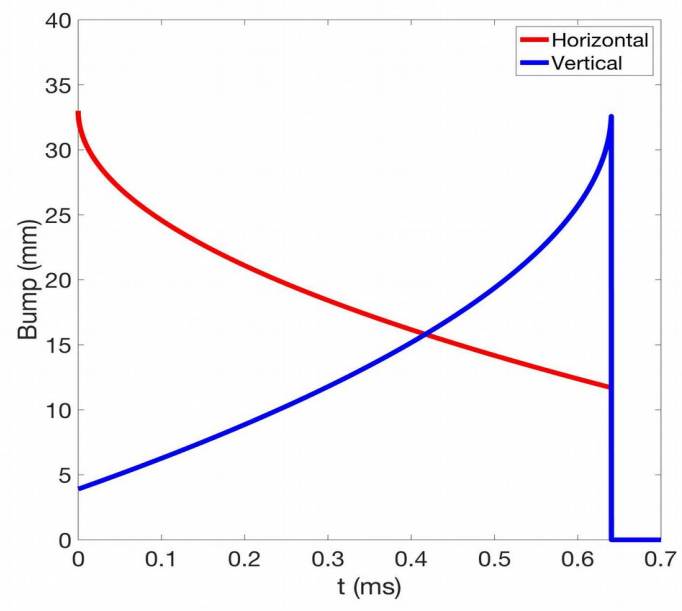

Ye Zou, Uppsala

# Transverse distribution

Beam distribution in real space




Anti-correlated painting bump

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# Tune and Emittance

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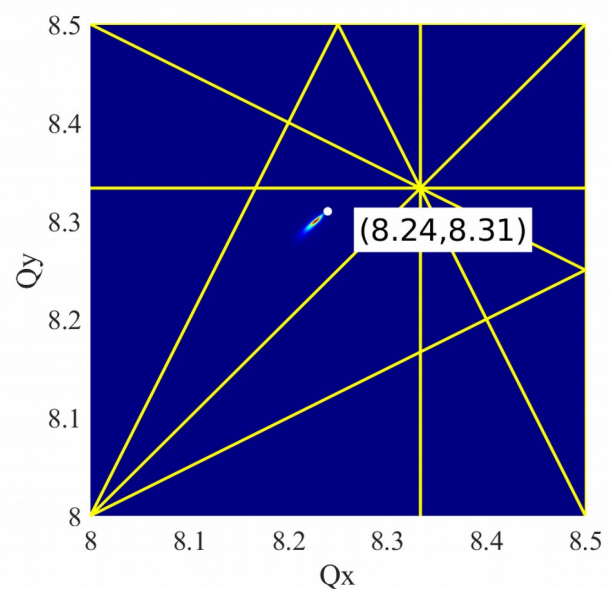
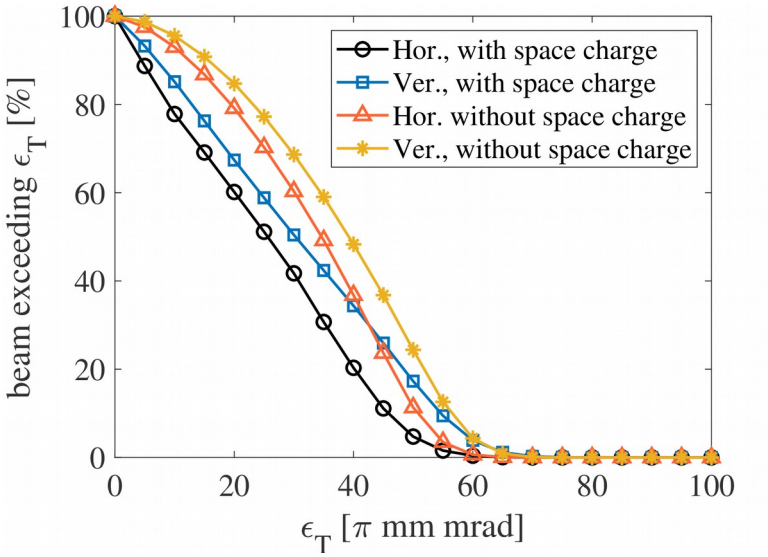
Tune distribution



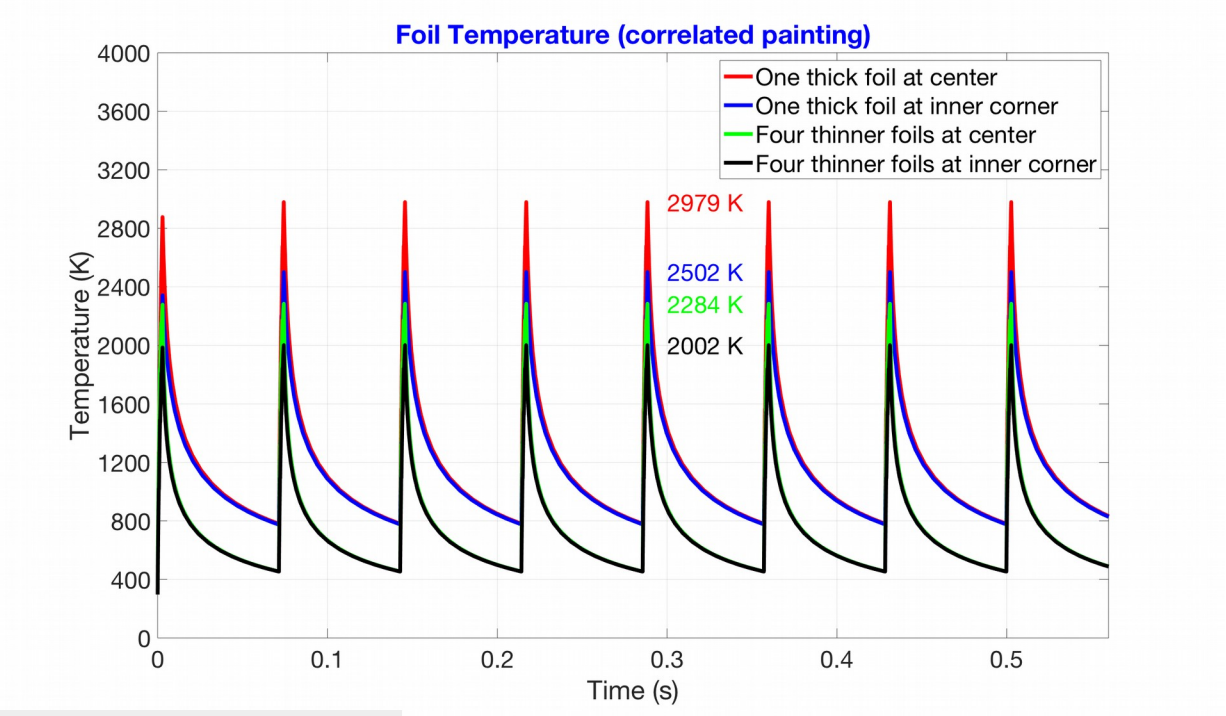

Total tune spread ~ 0.03

Emittance

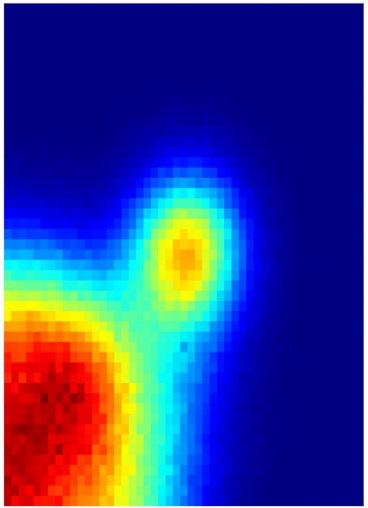



Emittance (100%) $\lesssim$ 70π mm mrad

# Stripper Foil Temperature: 1 Vs. 4 foils

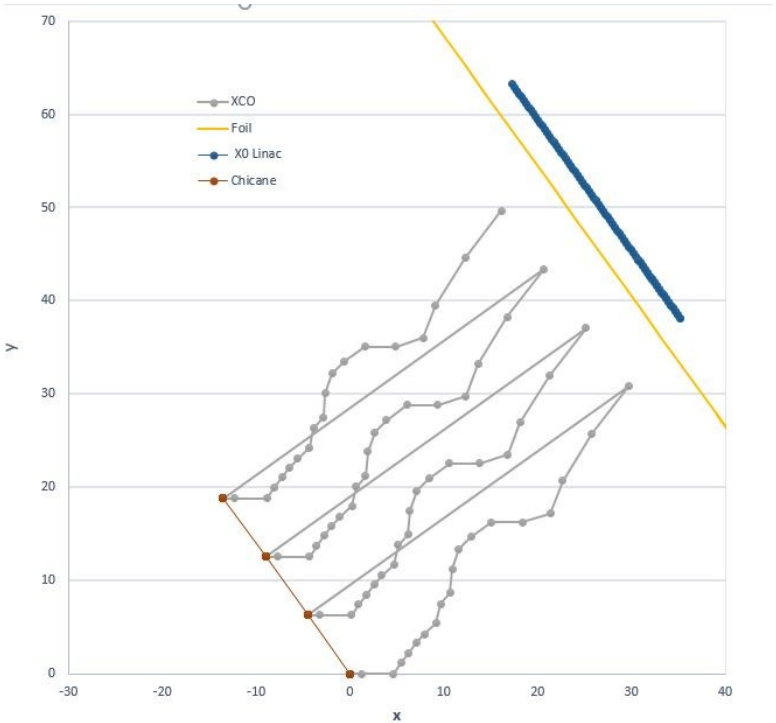


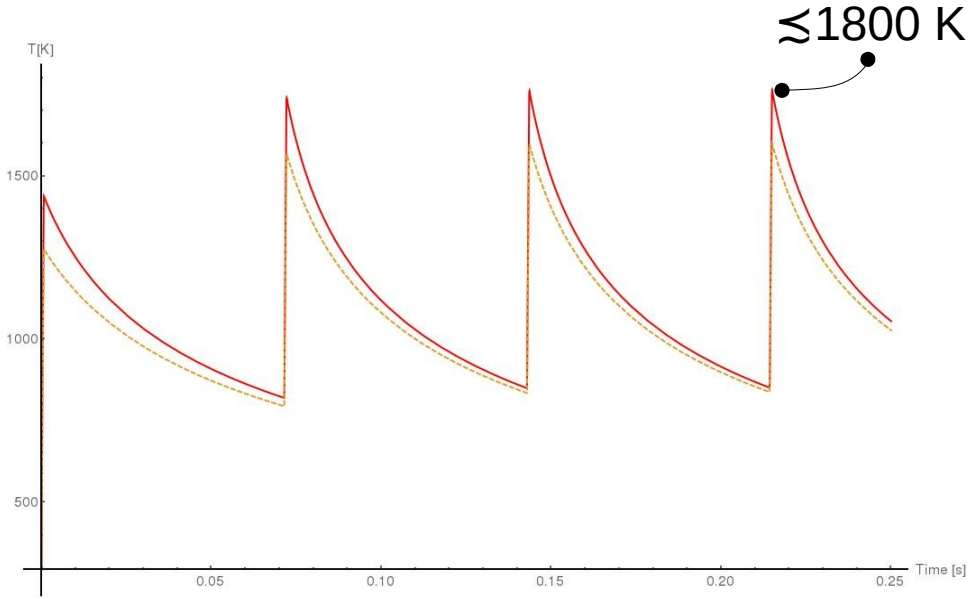

Proton density on the foil



Ye Zou, Uppsala

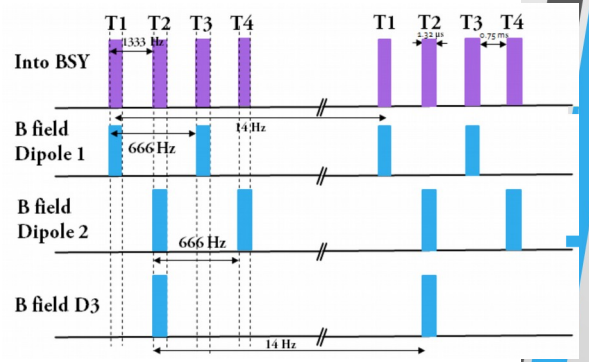
# Stripper Foil Temperature: Moving Injection Point



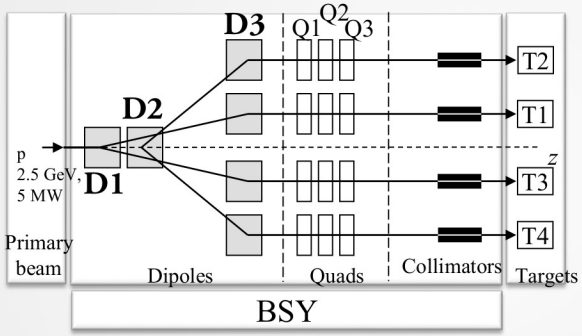




Horst Schönauer, CERN

# The Switchyard




## Updates of the principle 1

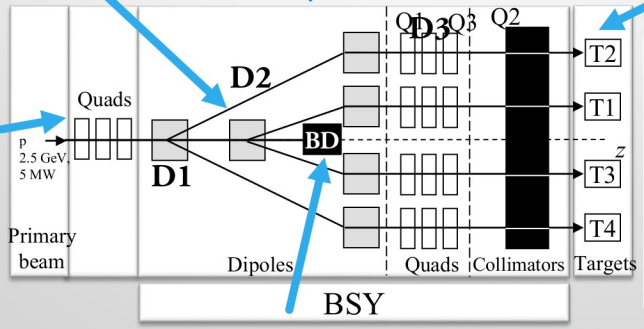



The beam deflected by D1 does not go through D2 but outside (to relax the constraints of D2 having consequent aperture)

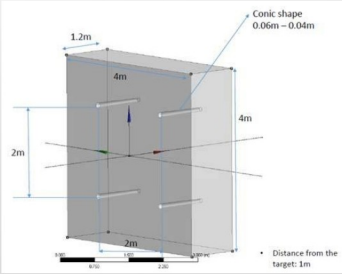
May 2019

Sept. 2019

Use of a single block of (carbon?) for collimation instead of 4 collimators




Addition of a triplet of quadrupoles at the entrance of the BSY

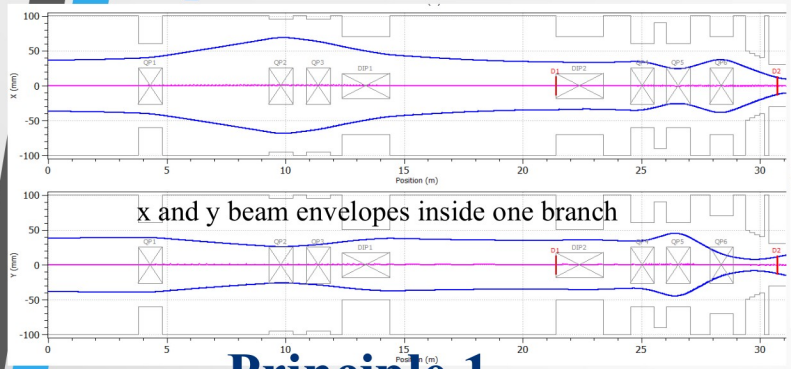


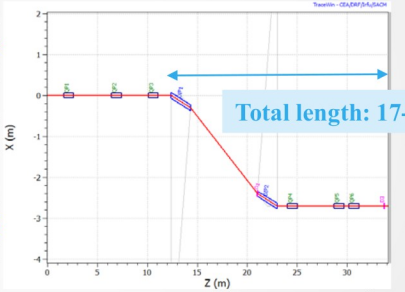

Addition of a beam dump after the 2 first dipoles

Elian Bouquerel

# The Switchyard

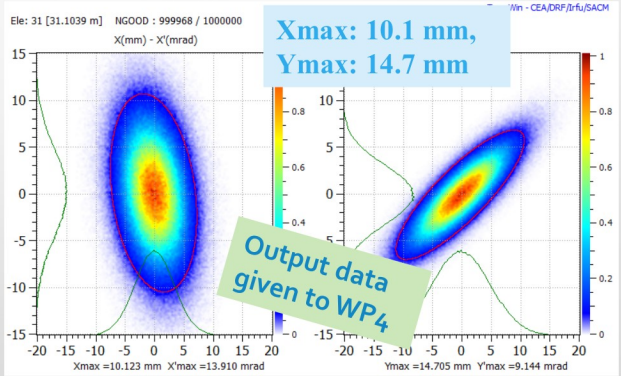
## Optimization of the BSY with the new input




synoptic

## Principle 1


Beam at target station

Dispersion estimated at 0.0637 mm at target

Elian Bouquerel

# To Do List for 2020

- **Accumulator operation scheme** (D3.1 end 2019)
- Foil stripping: mitigate foil temperature, continue investigating different options
  - M.P. HB2016: http://accelconf.web.cern.ch/accelconf/hb2016/papers/tupm6x01.pdf
- Collimation: Settling on the machine acceptance, collimator acceptance, and check that we can create a beam that fits.
- Extraction: Kicker design, extraction optics
- Transfer line: Freezing the overall geographical layout so that we can design the transfer line
- Full beam propagation from ring to target.

# Thanks to

The WP3 Team! In particular

Ye Zou
Horst Schönauer
Elian Bouquerel
Elena Wildner
Karl-Fredrik Kylesten

Thanks also to WP2 and WP4 for good cooperation!

# Extra

# Milestones and Deliverables in 2019

MS1 Review of the 1st year achievements, deliverables & costs

MS4 Evaluation of the Accumulator requirements (2018)

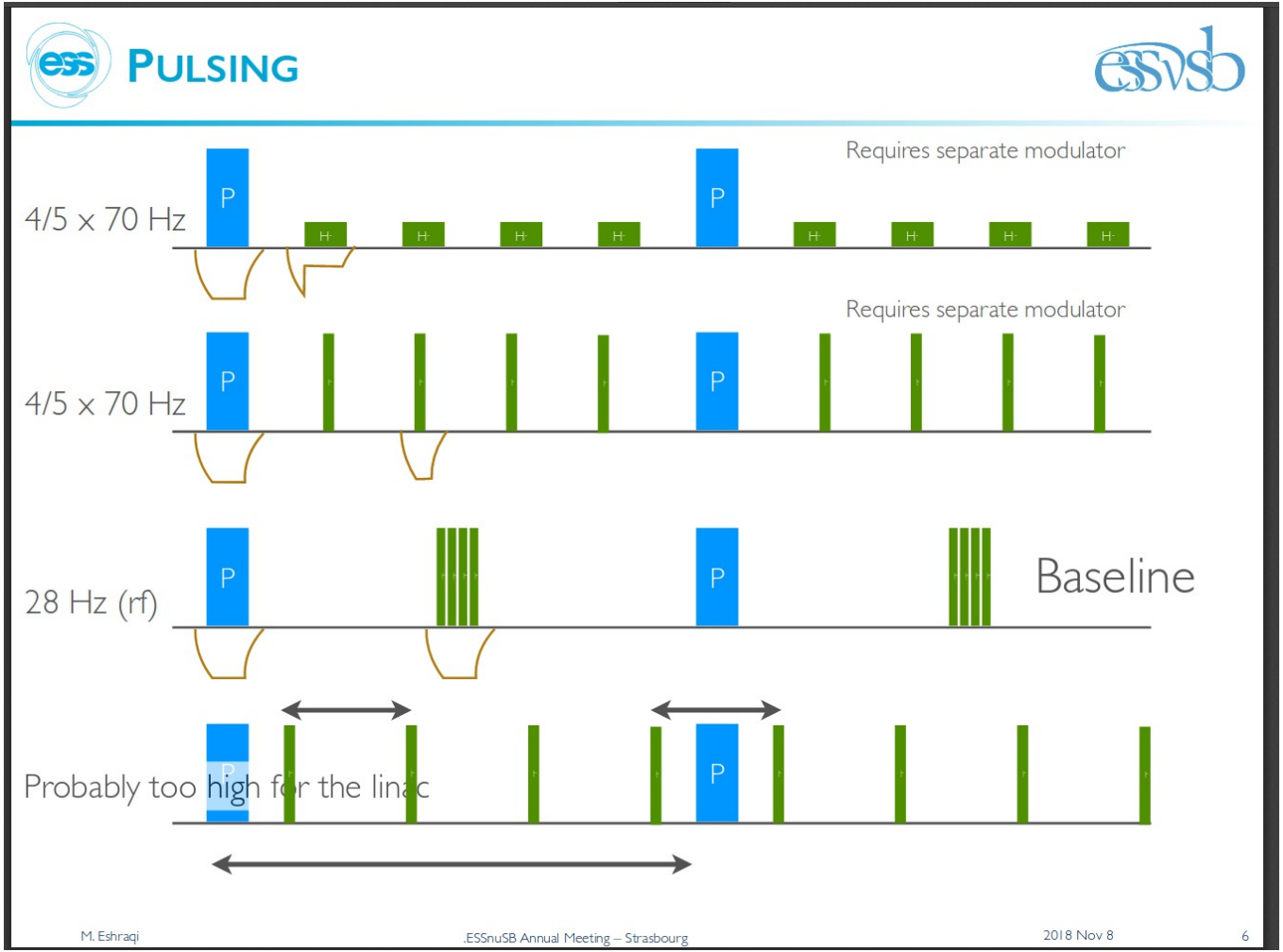
MS6 The accumulator lattice design

D3.1 Accumulator operation scheme

# Milestones and Deliverables in 2020

MS9 Review on interim milestones, deliverables and costs

D3.2 Transfer lines layout and design, extraction and switchyard design

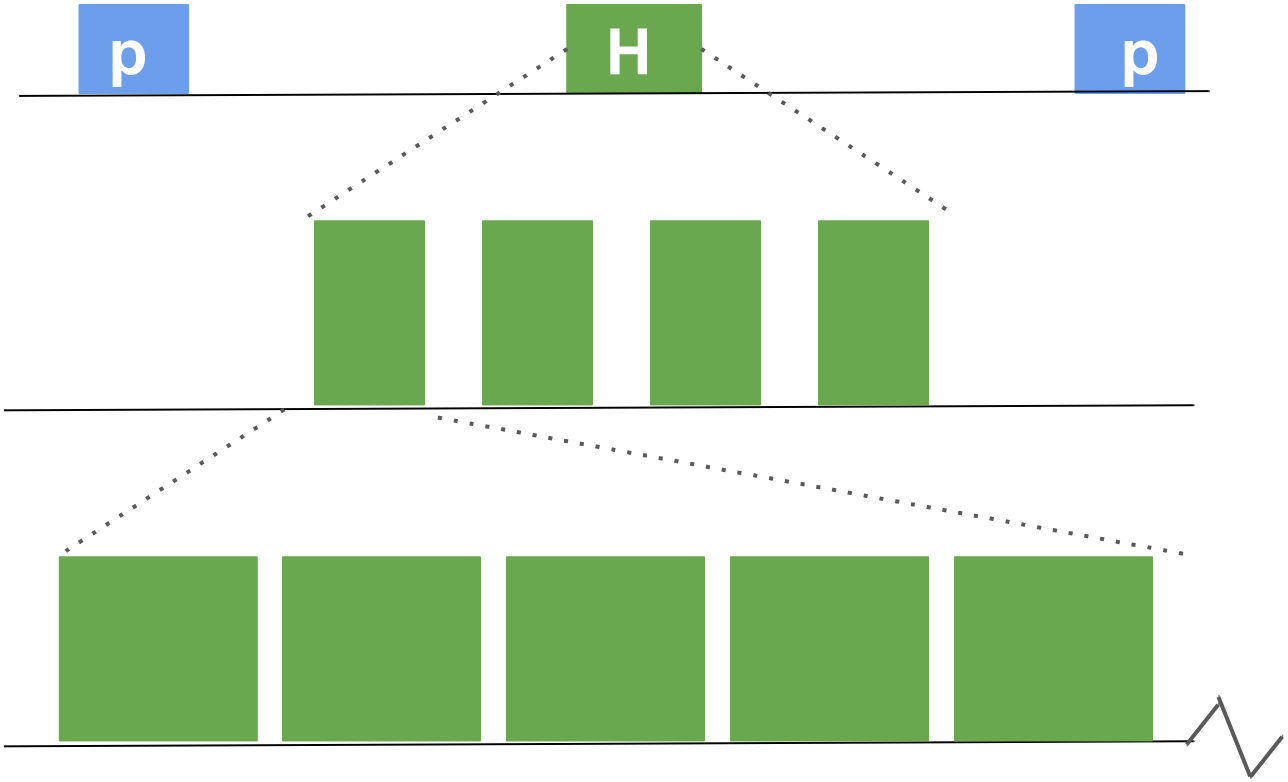



From Mamad's Summary of WP2 talk Strasbourg, 2018.

# What we need

“Injection” gaps
100 μs long,
Three gaps =>
four batches

“Extraction” gaps
133 ns long, every
1.33 μs.s



# What we would prefer