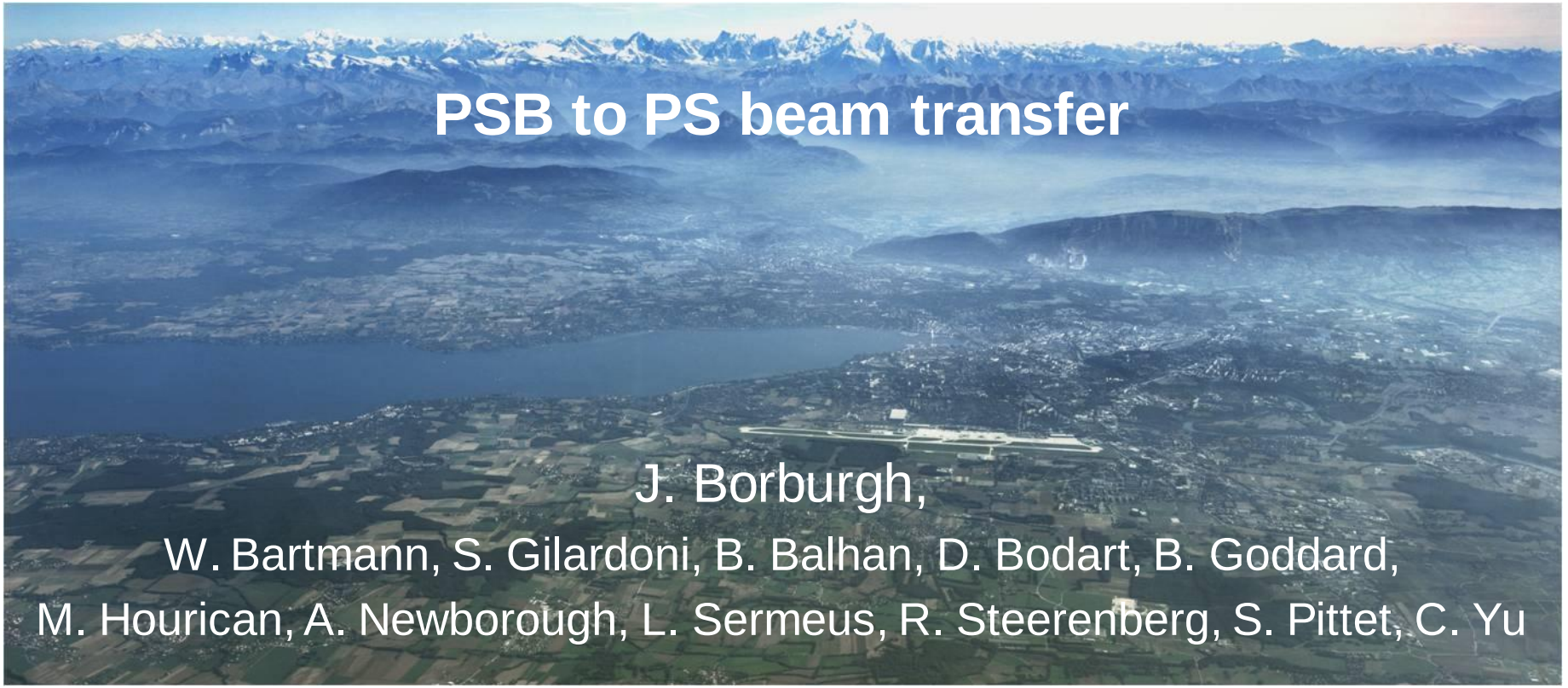
LHC Injectors Upgrade



PSB to PS beam transfer

J. Borburgh,
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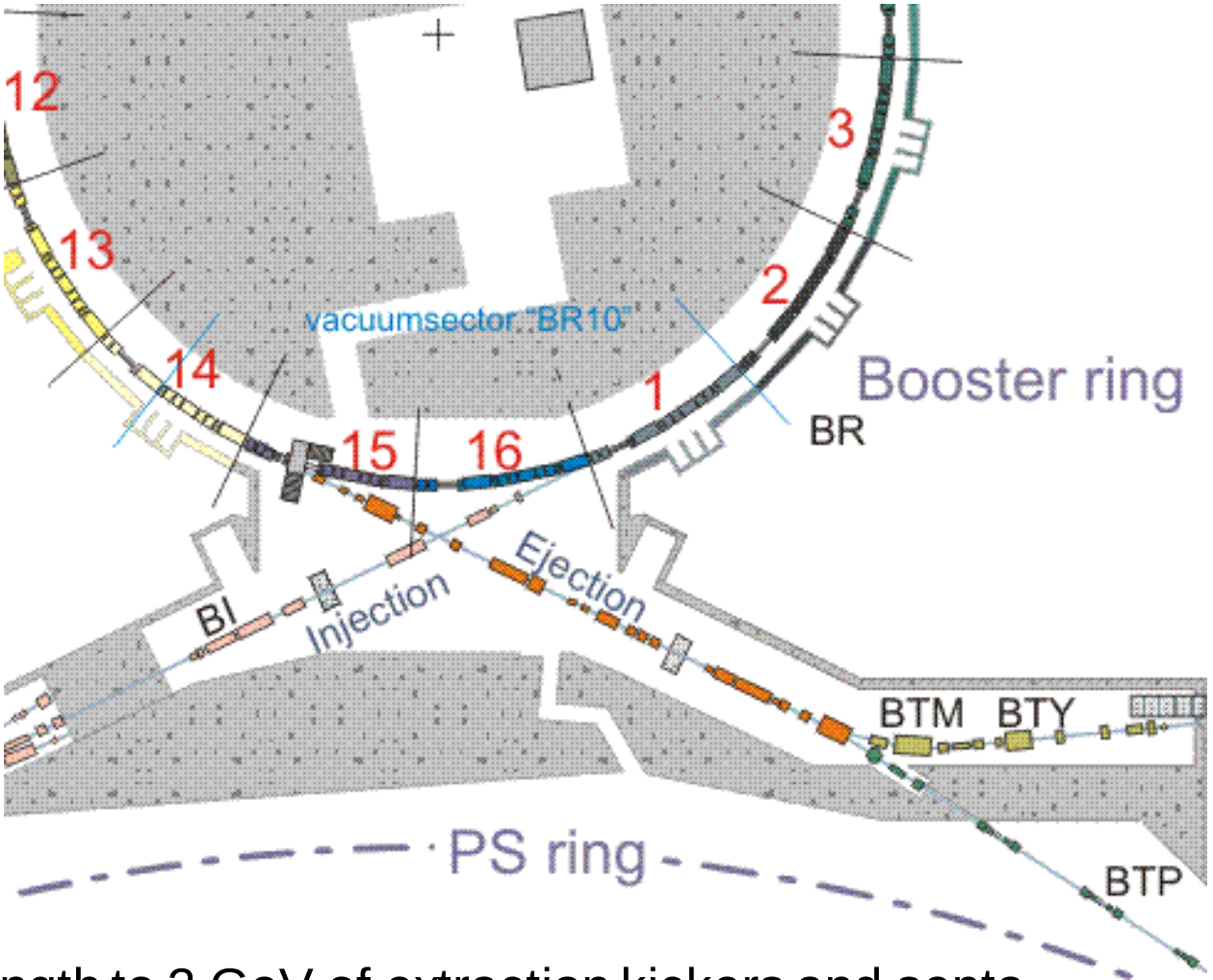
CERN

Outline

I. **Booster extraction**
II. BT - line
III. BTP – line
IV. PS injection
V. Summary

Beam transfer from PS Booster to PS



Extraction at PSB:

increase element strength to 2 GeV of extraction kickers and septa

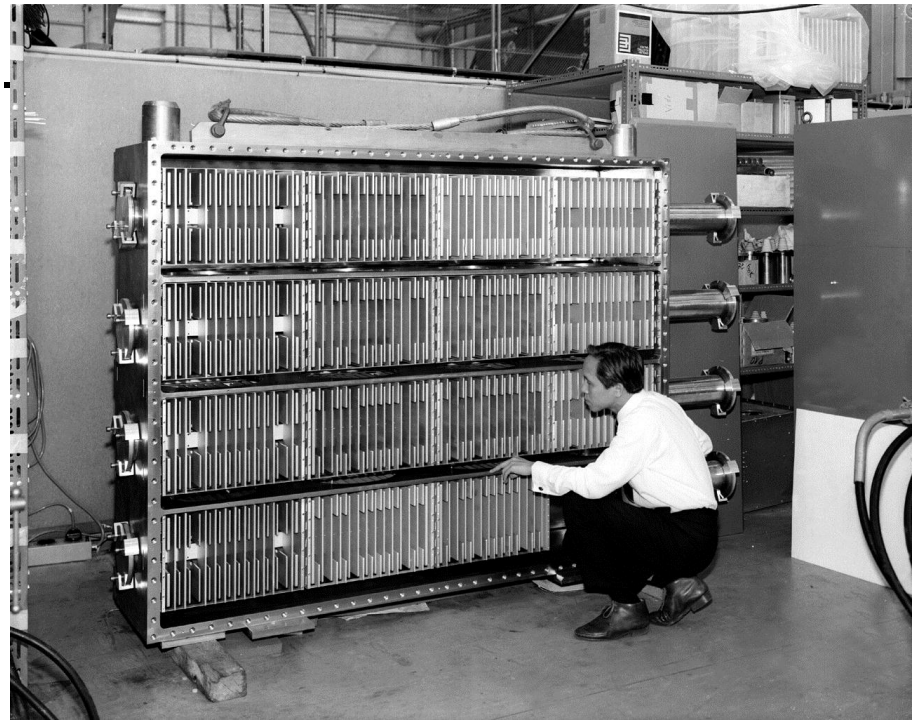
PSB extraction kickers KFA14L1

Magnets installed under vacuum.
4 delay line magnets in parallel (Z_0 = 25 Ω) per booster ring.
1 generator per booster ring.

Gas filled Pulse Forming Line rated at 60 kV.

- V_{PFL} (@1.4 GeV): 42.5 kV
- V_{PFL} (@2 GeV): 55 kV

At 2 GeV actual magnets would saturate.

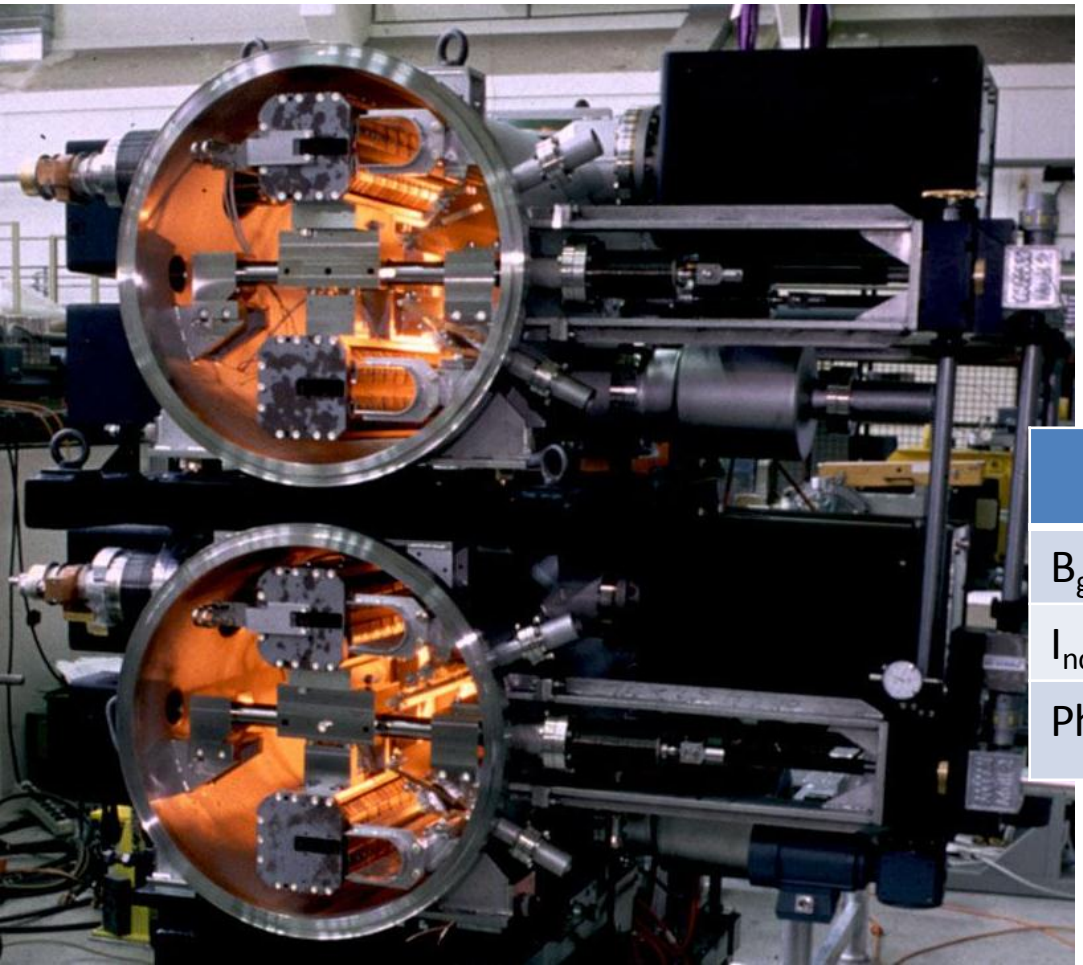


- Conclusion:

  New extraction kickers required.

Booster Extraction septa (BE.SMH)

Under vacuum, laminated steel magnets; Strength increase obtained by increase of the nominal current. Modifications required to cooling and electrical connections.



	1.4 GeV	2 GeV
B_{gap} (T)	0.35	0.46
$I_{nominal}$ (kA)	7.2	9.4
Physical length (mm)	1000	1000

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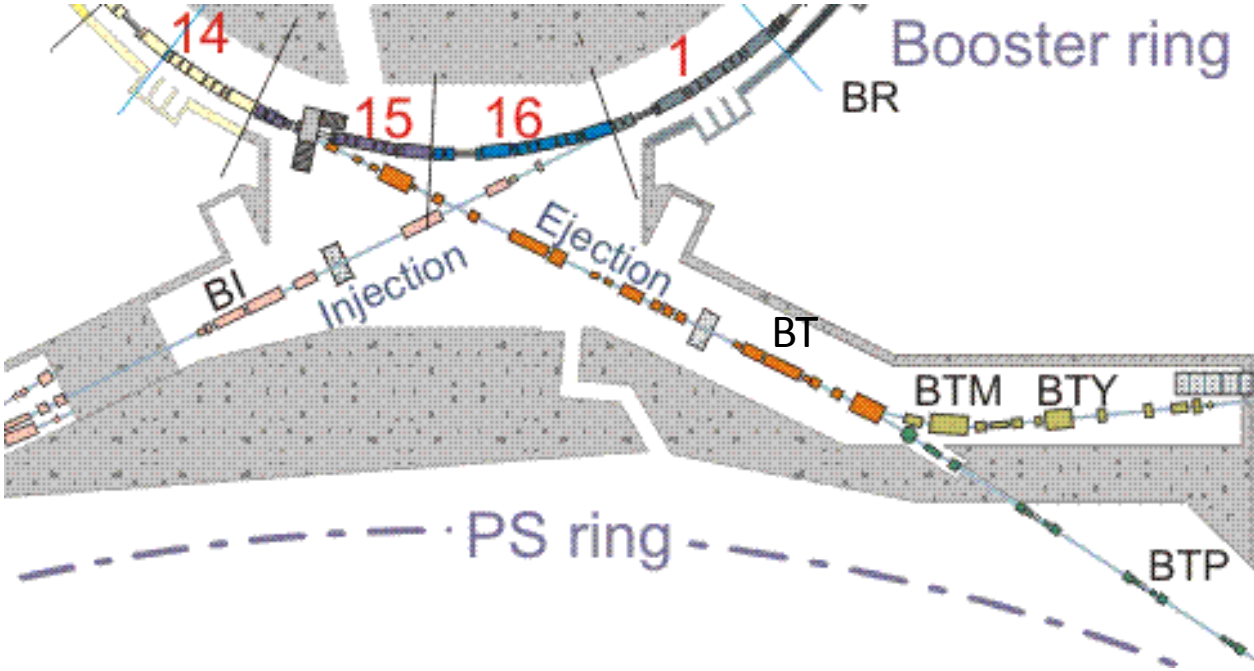
BT recombination line



Fundamental characteristics:

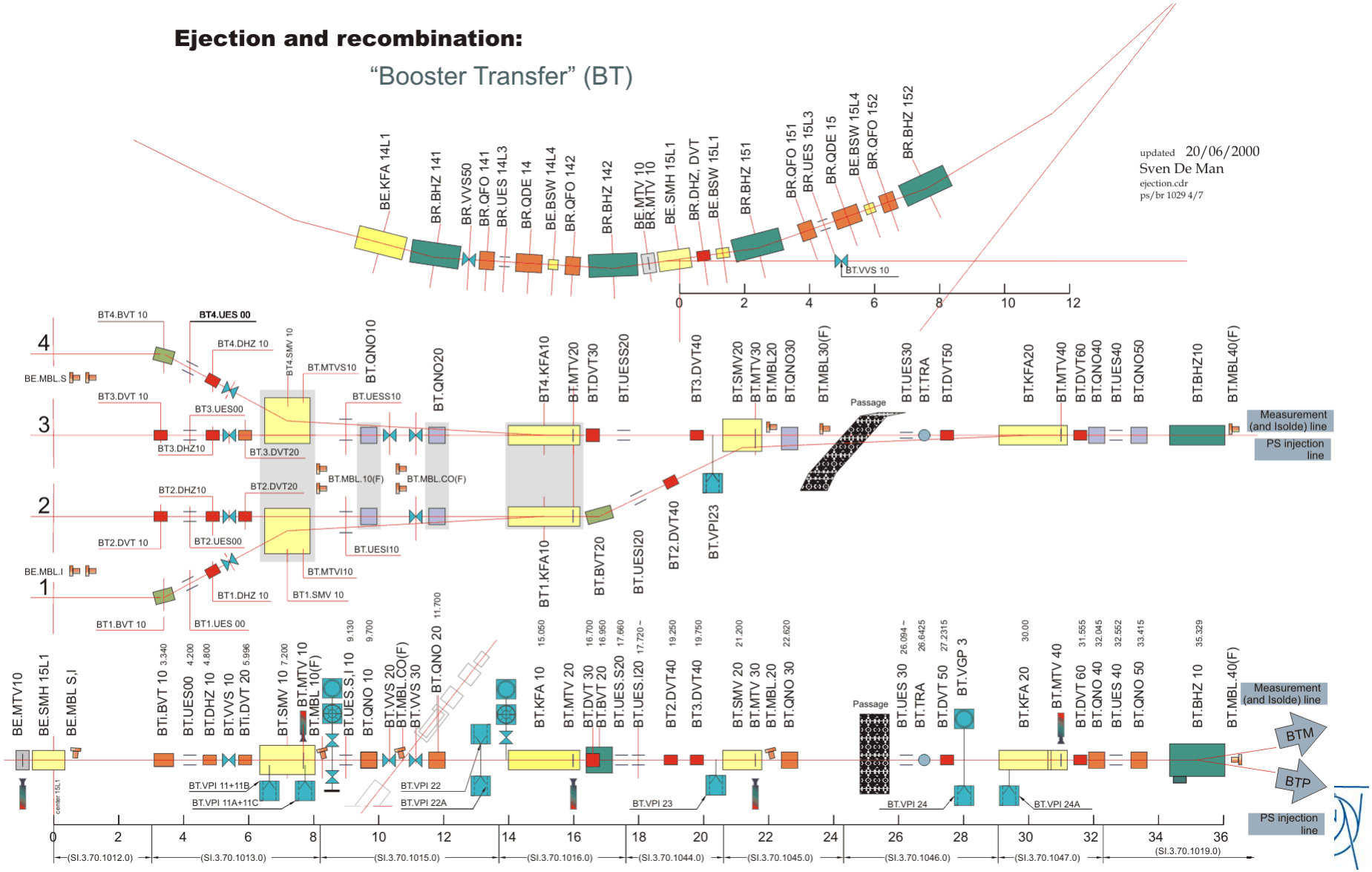
Presently the line can switch cycle to cycle (ppm) between 1.0 GeV to 1.4 Gev.
After the upgrade the line will be ppm between 1.4 GeV to 2.0 GeV.

No fundamental optics changes foreseen for the upgrade.

Modification of switching dipole BHZ 10 towards the BTP line.
Upgrade of recombination septa,
Kickers are already capable to deflect 2GeV beam.

BT (booster recombination) line

Ejection and recombination:



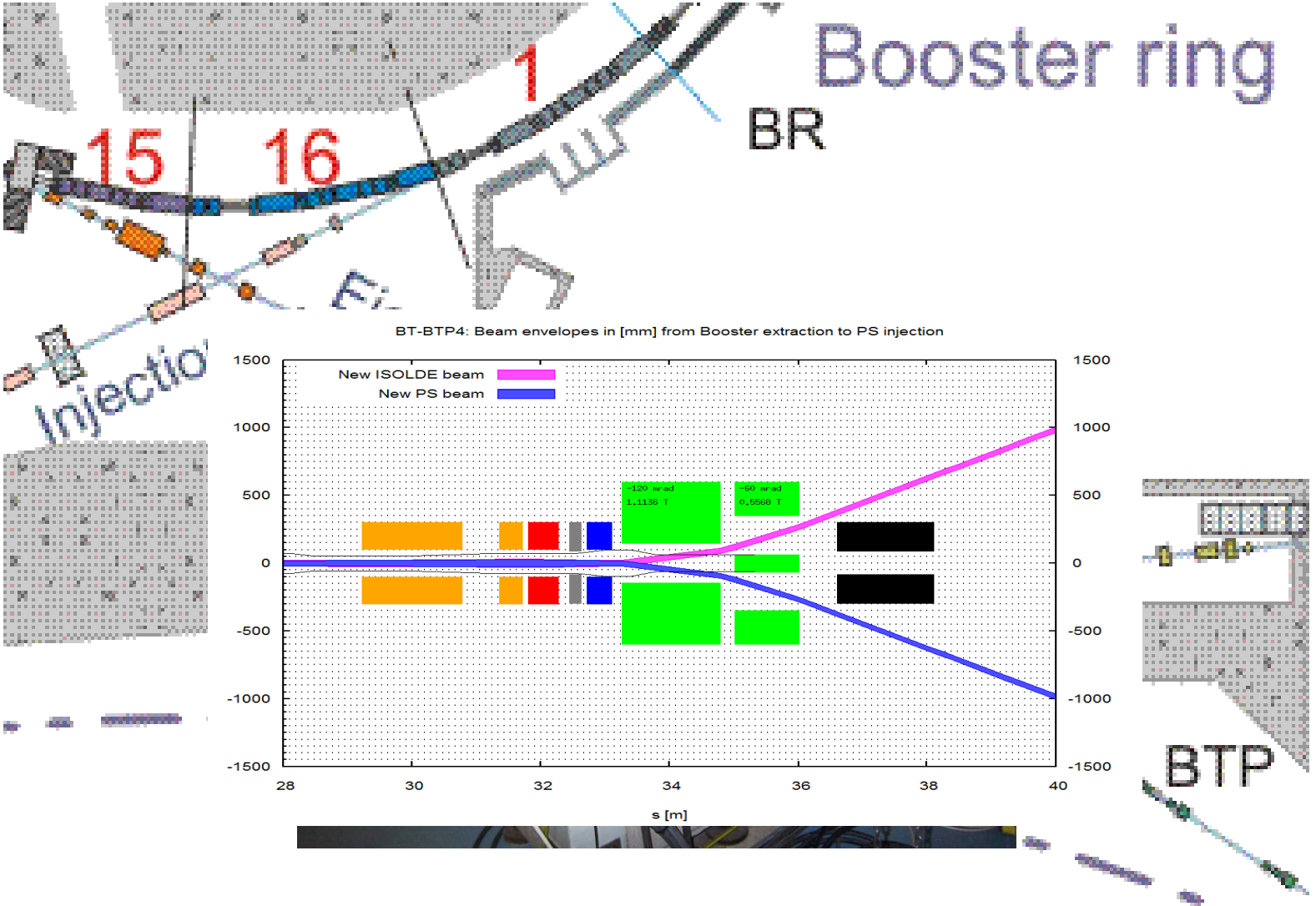
Recombination septa

Under vacuum magnetic septa. Increase in strength will be achieved mainly by increasing the length of the magnet. The vacuum vessel will remain unchanged.

	Present 1.4 GeV	2 GeV
B_{gap} (T)	0.57	0.6
$I_{nominal}$ (kA)	27.3	28.6
Physical length (mm)	1060	1300
Magnetic length (mm)	997	1237

Switching dipole towards BTP line

3 solutions for BHZ 10 under investigation.



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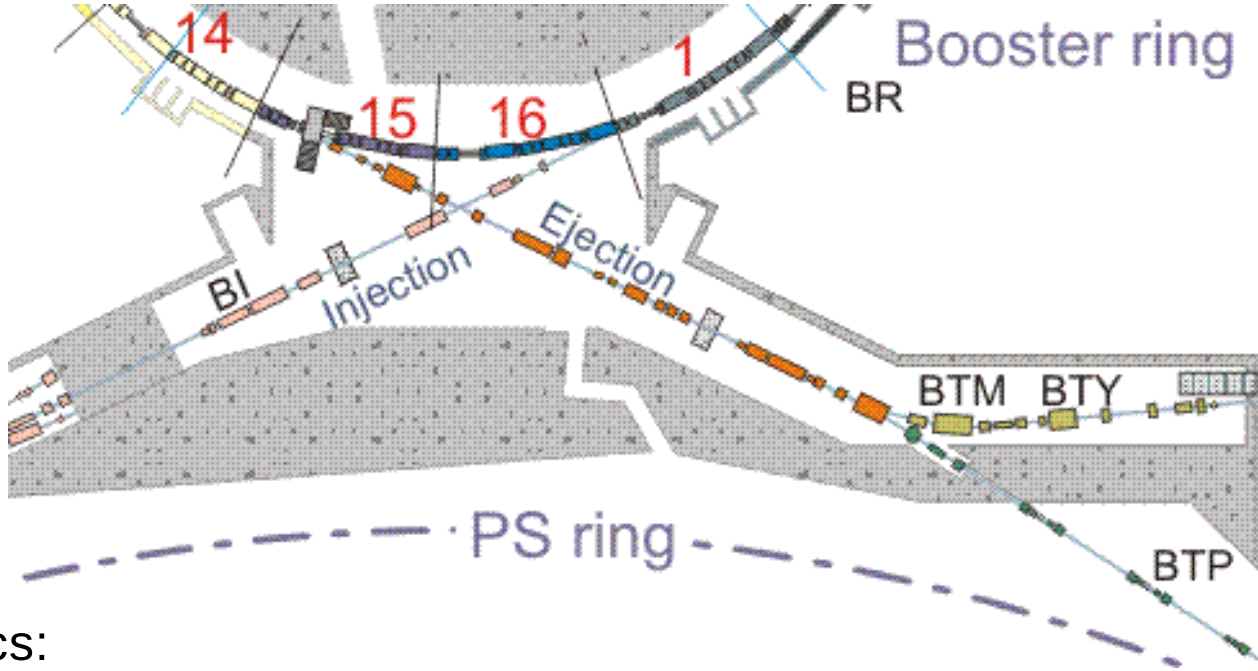
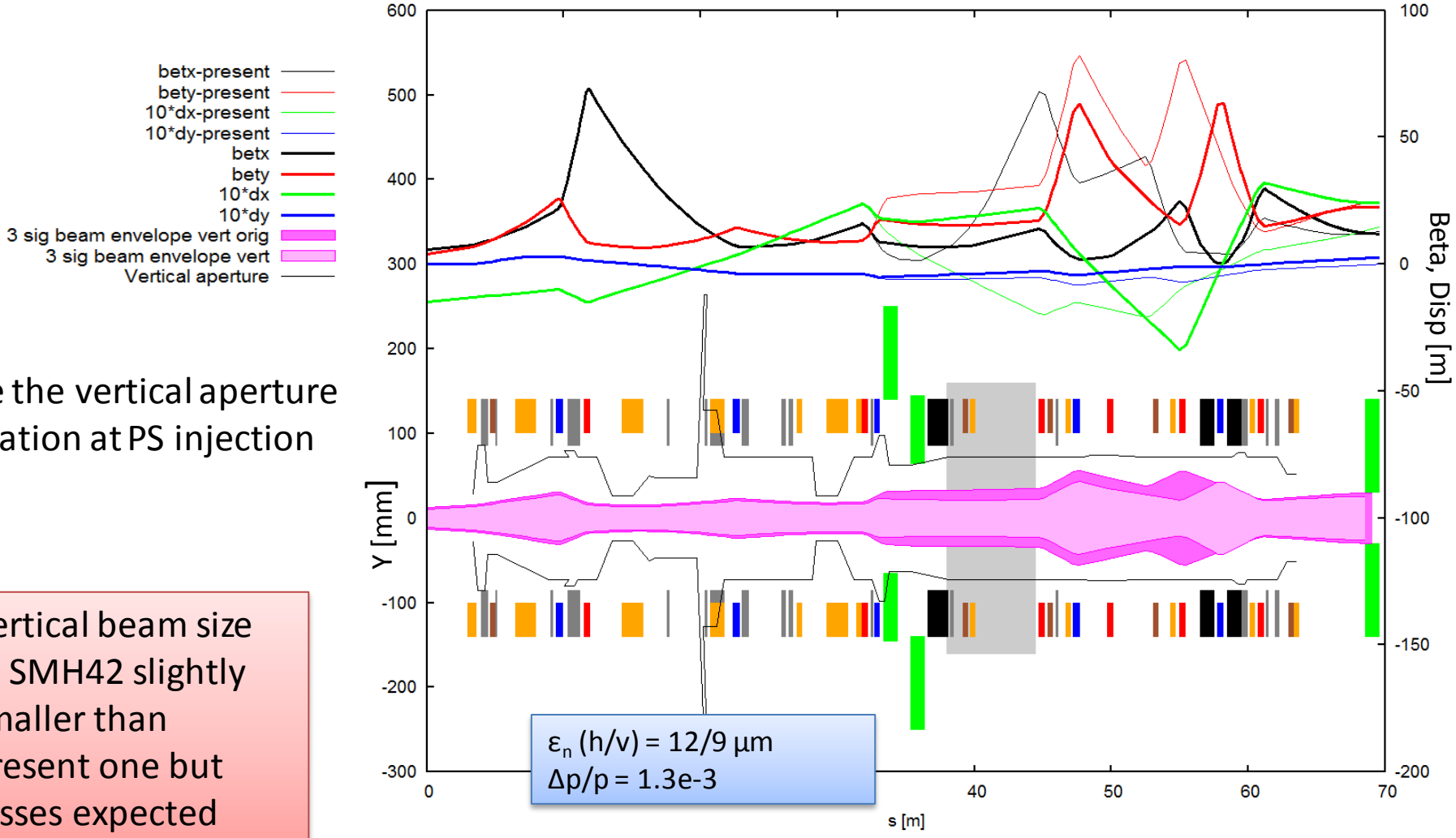
BTP (Booster to PS) line



Fundamental characteristics:

- Presently a DC line.
- Will become ppm between 1.4 GeV to 2.0 GeV
- Optics will be adjusted as a function of beam type (LHC vs. High intensity)
- New optics
  - avoids use of elements installed in the PS wall.
  - needs 1 additonal quadrupole on PS side
- May include collimation to limit activation of PS injection septum

BTP line optics with matched optics (LHC)

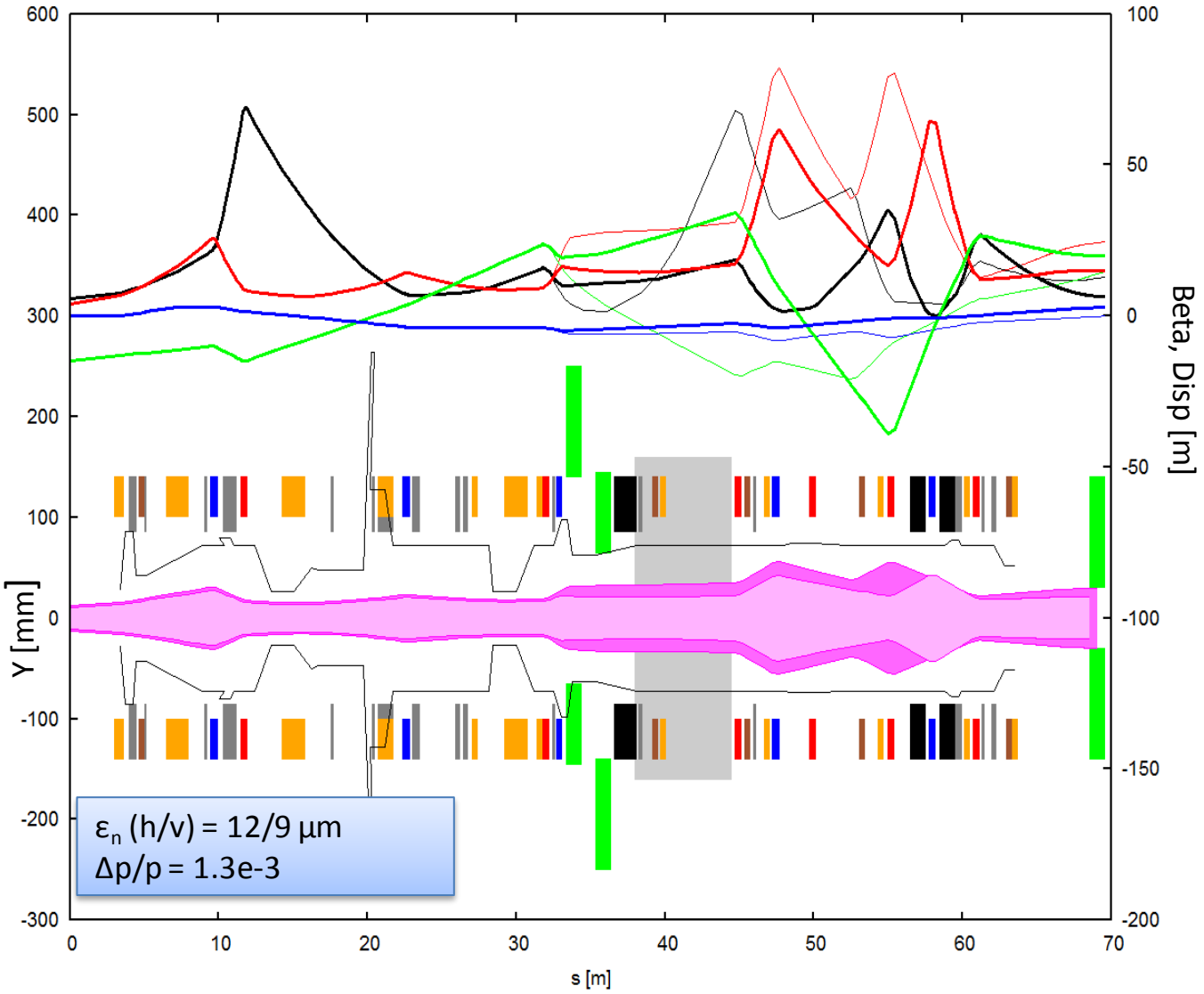


Note the vertical aperture limitation at PS injection

Vertical beam size at SMH42 slightly smaller than present one but losses expected

BTP line optics for High Intensity beam profiles in vertical plane

BTP line optics with reduced beam size at PS entrance



BTP line with reduced beam size HI optics.

Vertical beam size at SMH42 reduced w.r.t. to LHC and present settings

BTP line optics for High Intensity beam profiles in vertical plane

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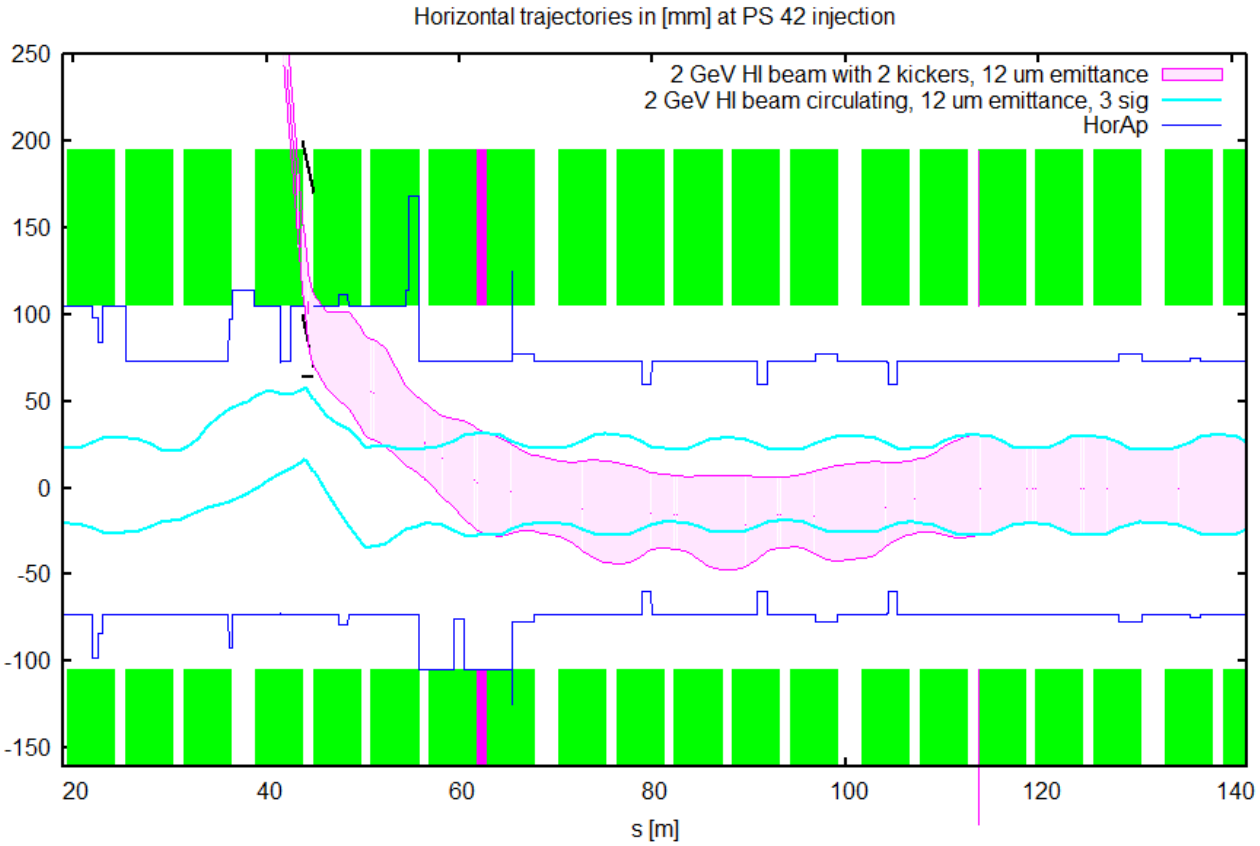
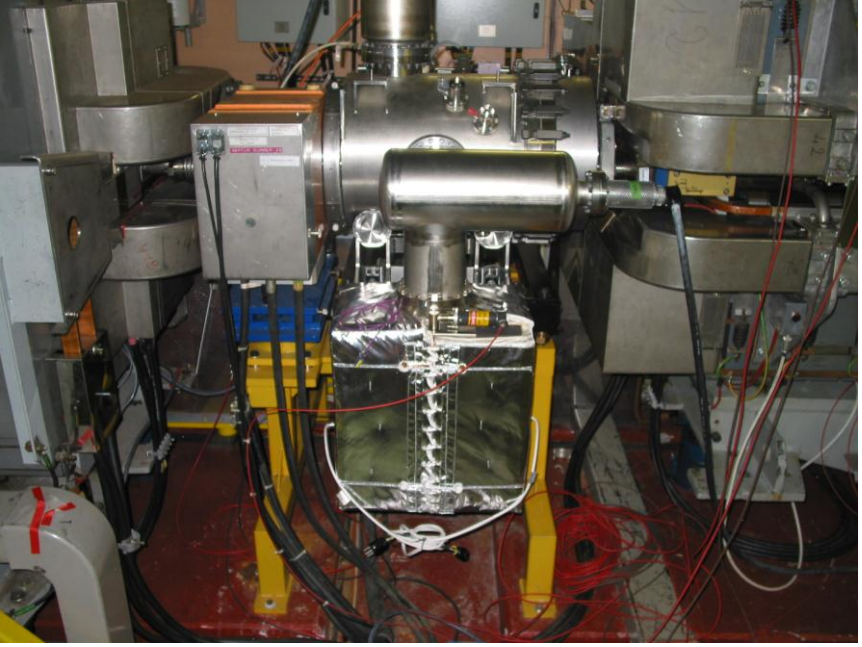
PS injection

LHC beam injected using new septum and existing kicker

High Intensity beams injected using new septum, existing plus new kicker



PS injection optics, using 5 bumpers, KFA45 and KFA53.



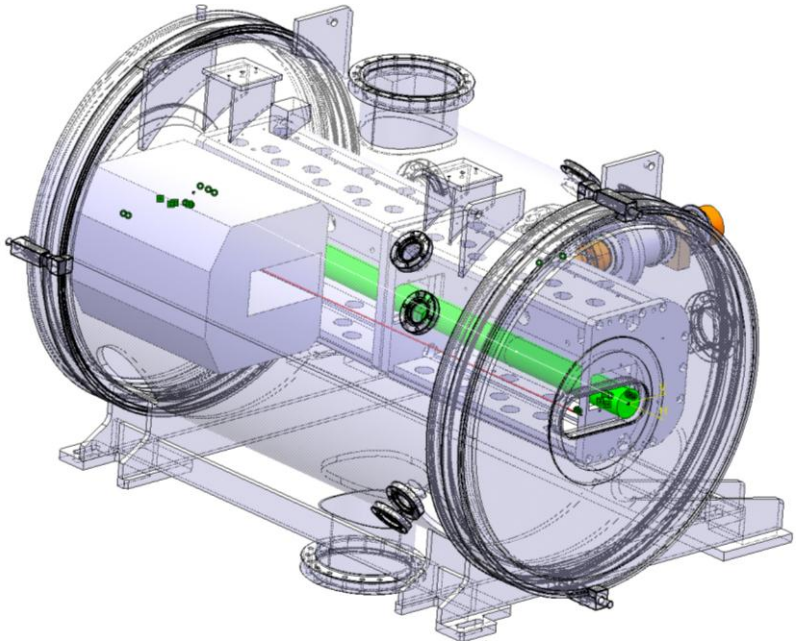
PS Injection septum 42

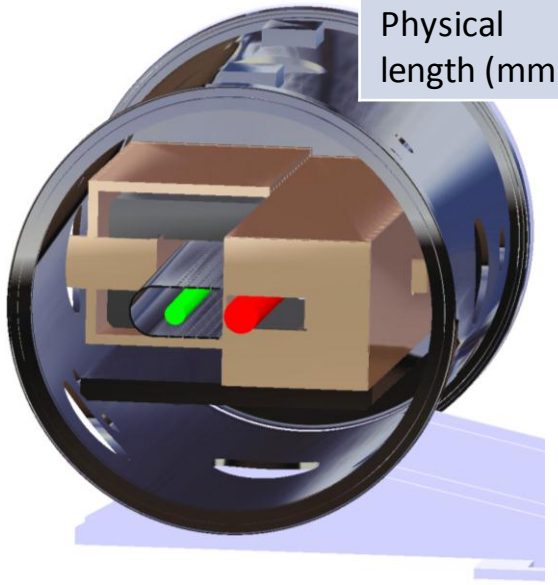
Concepts developed:

1. direct drive (left)
2. eddy current (right) variants

Less experience at CERN with eddy current devices, but possibly more robust (R&D required).

	1.4 GeV	2 GeV
B_{gap} (T)	0.7	0.7
$I_{nominal}$ (kA)	33.5	33.6
Physical length (mm)	620	790





PS Injection bump

Strive for shorter injection bump to limit the continuous losses. Feasibility still to be investigated.

5 magnets will be needed instead of 4:

- 4 outside vacuum multi-turn bumpers
- 1 under vacuum single turn magnet installed in injection straight section

Delay in field between outside vacuum and under vacuum bumpers being investigated at present.

Tracking precision between different bumpers challenging for power supplies.

PS injection kickers KFA 45

4 kicker modules installed under vacuum.
Gas filled Pulse Forming Line rated at 80 kV.

Can be used in short circuit or terminated mode:

V_{PFL} (@1.4 GeV): 80 kV (limit of system);
V_{PFL} (@2 GeV): only in short circuit mode, 60 kV;

Drawbacks of short circuit mode:

- flattop ripple from ± 2 % to ± 3;
- post pulse ripple from ± 1.25 % to ± 1.5 %;
- rise time (2-98)% from 42 to 68 ns;
- fall time (98-2)% from 68 to 87 ns;

New to build PS injection kicker KFA 53

Additional short and fast kicker required.

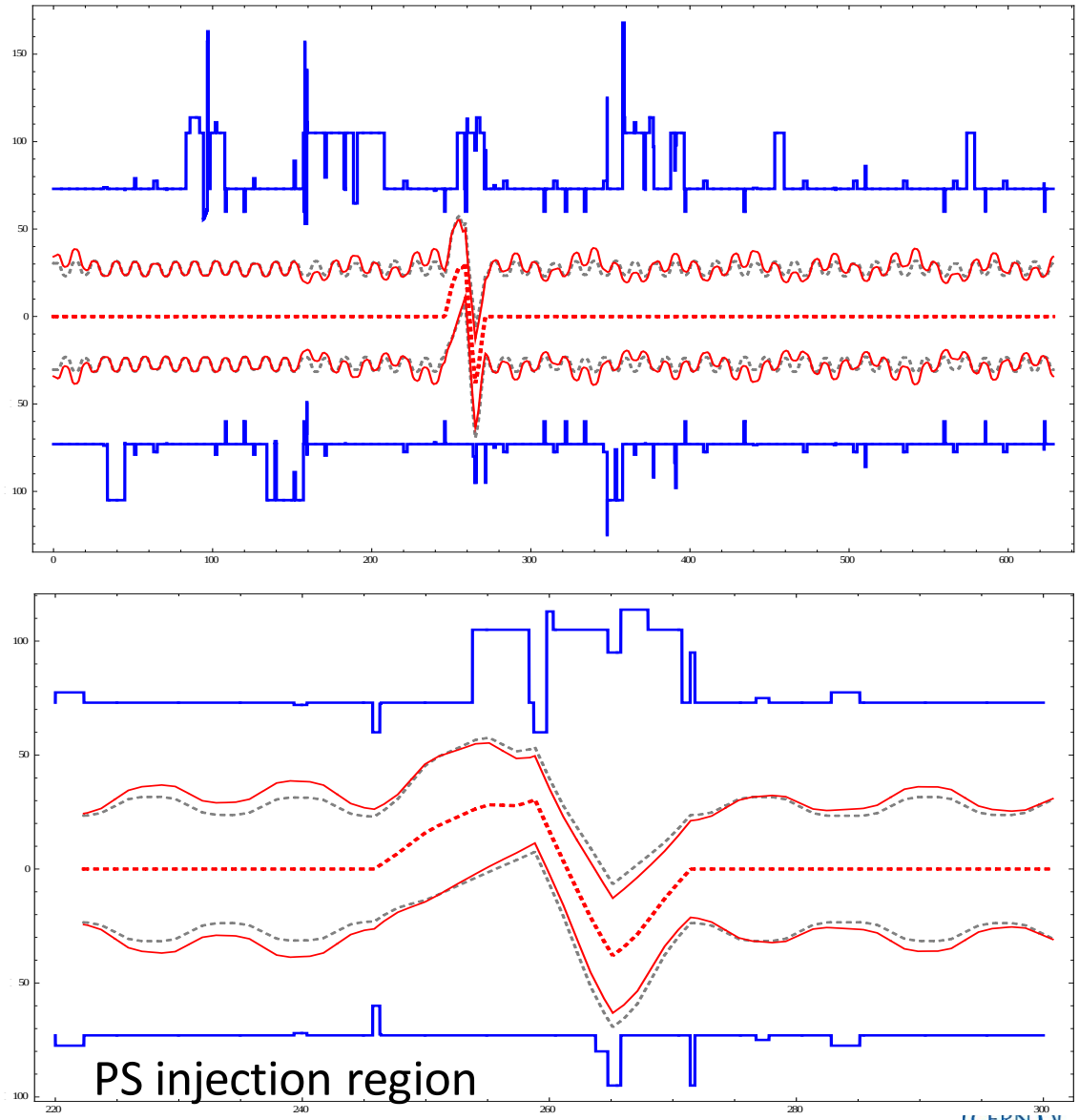
Development will start next year.

	nominal	maximum
Deflection angle [mrad]	1.2	1.5
∫B.dl [mT.m]	11.5	13.9
PFL voltage [kV]	23.8	29.7
Magnet current [A]	793	991
No of magnets	4	
Magnet impedance [Ω]	30	
Magnet gap (w×h) [mm^2]	140 × 59	
Magnet length [mm]	158	

PS injection optics

Creation of a low β region at the injection septum to limit the continuous losses during injection being studied.

Study using QKE's and verification of PS acceptance with 2 GeV beam injected.



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Summary

- ✓ Hardware to be modified is identified and its feasibility studied.
- ✓ 2 different optics of the transfer line are required for LHC (matched) and High Intensity beams (reduced beam size at entrance of PS).
- ✓ BTP line to be re-designed, taking into account new BHZ10 layout and possibly collimation.

- ➢ PS injection optics under study to create a low β insertion around septum.

Main challenges:

- ➢ Injection septa (septum and bumper).
- ➢ Injection bumper tracking precision (power convertors, magnets).
- ➢ Additional PS injection kicker with high strength, very limited space and fast rise and fall time requirements.