Brighter Beams for LHC - New PSB H^- injection and PS 2GeV transfer

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with many inputs from

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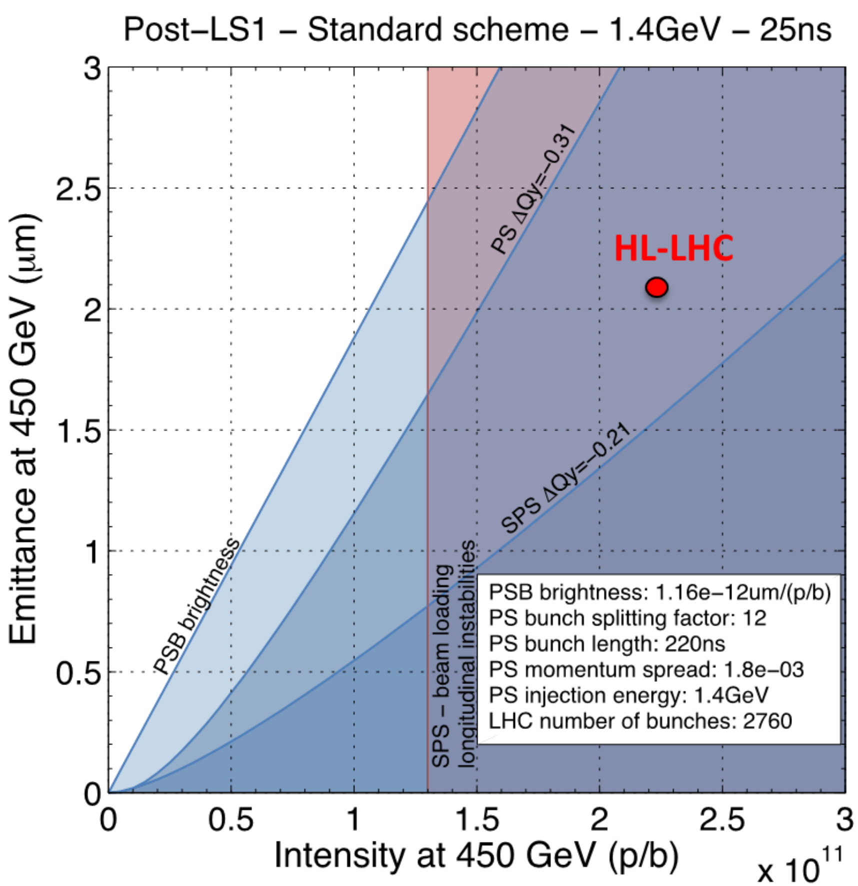
HB2014, 12-Nov-2014

Outline

- Motivation – Injector brightness limitations
- PSB injection
  - 50 to 160 MeV
  - Charge exchange
- PSB extraction and recombination
  - 1.4 to 2 GeV
- Transfer optics
  - Remove dispersion mismatch
  - Dedicated optics per beam
- PS injection
  - 1.4 to 2 GeV

Injector brightness limitations



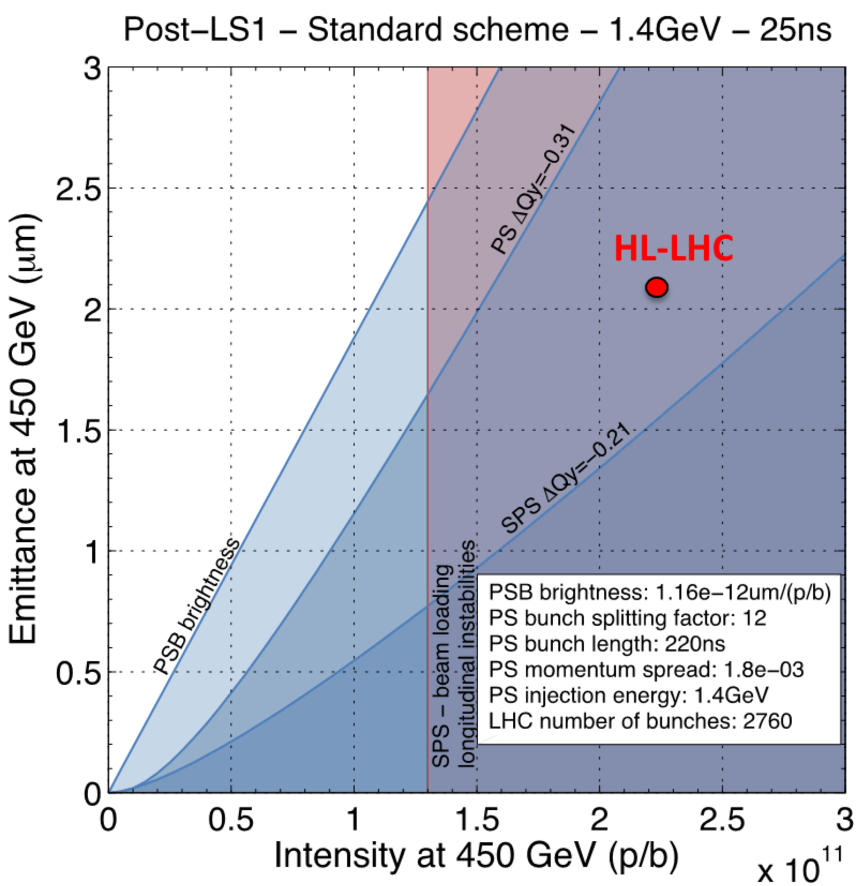
PSB

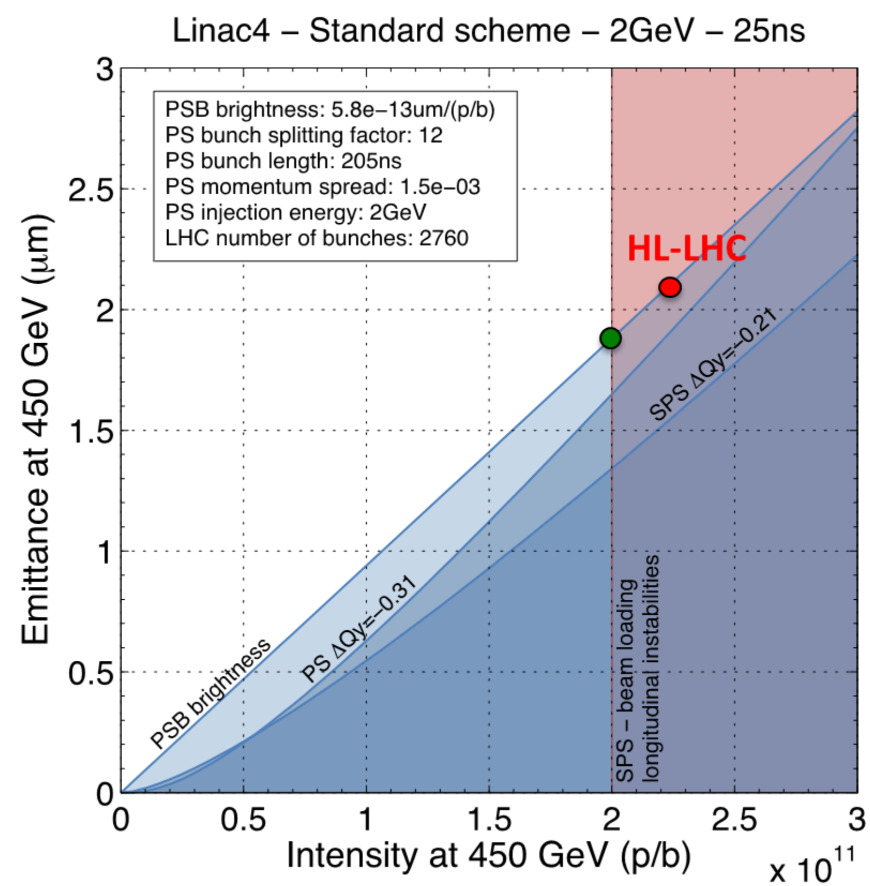
- 50 → 160 MeV
- Charge exchange injection

PS

- 1.4 → 2 GeV

Injector brightness limitations





Present PSB injection: Vertical distribution

Present PSB multiturn injection

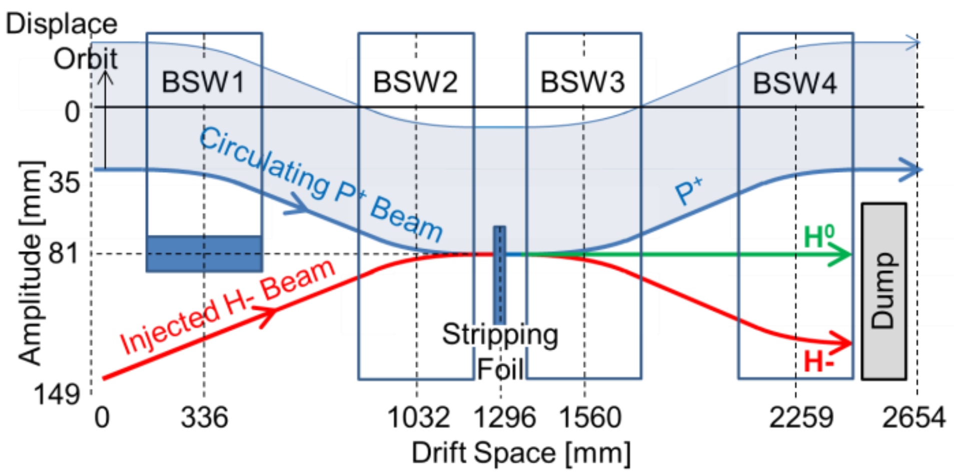
40% of Linac pulse lost

New PSB injection – vertical separation

- Chop kicker gaps into Linac pulse
- Distribution kickers
  - Short circuit distributor magnets
- Distribution septum
  - Steel instead of ferrite magnets
  - Higher current
  - Smaller width to reduce mechanical forces

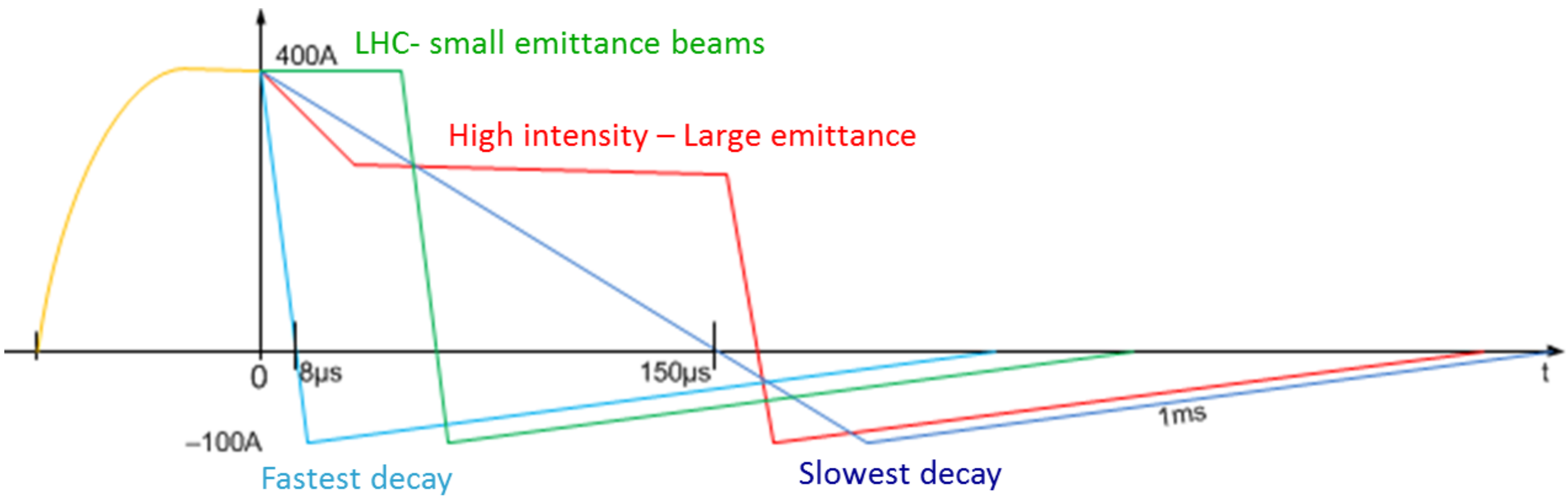
PSB injection – horizontal injection

- Charge exchange injection
  - 160 MeV H- from Linac4
  - 2.5 m space for chicane, foil, instrumentation and dump
  - Painting bumpers outside foil straight section
  - Full metal dump
  - Instrumentation:
    - Screen
    - Ionisation chambers and diamond loss detectors
    - H^-/H^0 current monitor



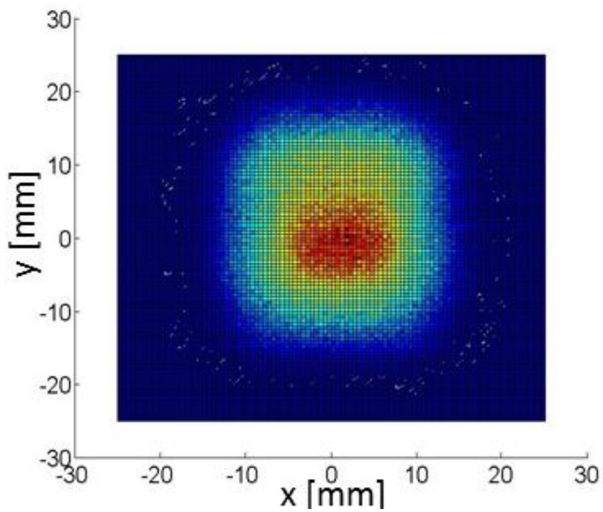
Painting envelope

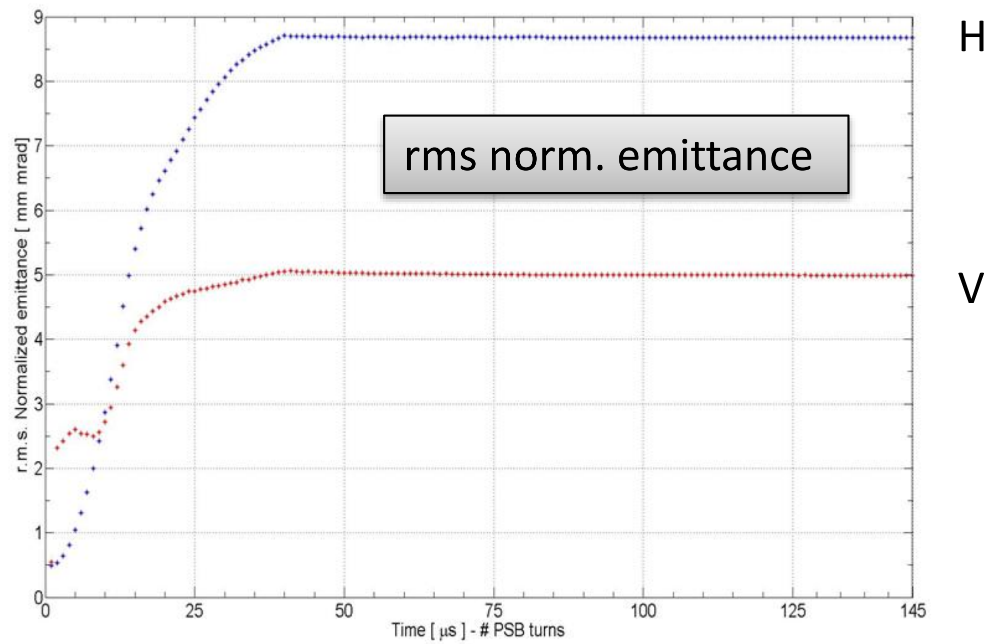
- Simulation with ORBIT
- Foil heating no issue – painting constraints from beam physics
- No painting for LHC beams, about 10-15 turns



High Intensity beam painting

- 100 - 150 turns painting for HI beams
- Horizontal position variation, vertical fixed offset in angle

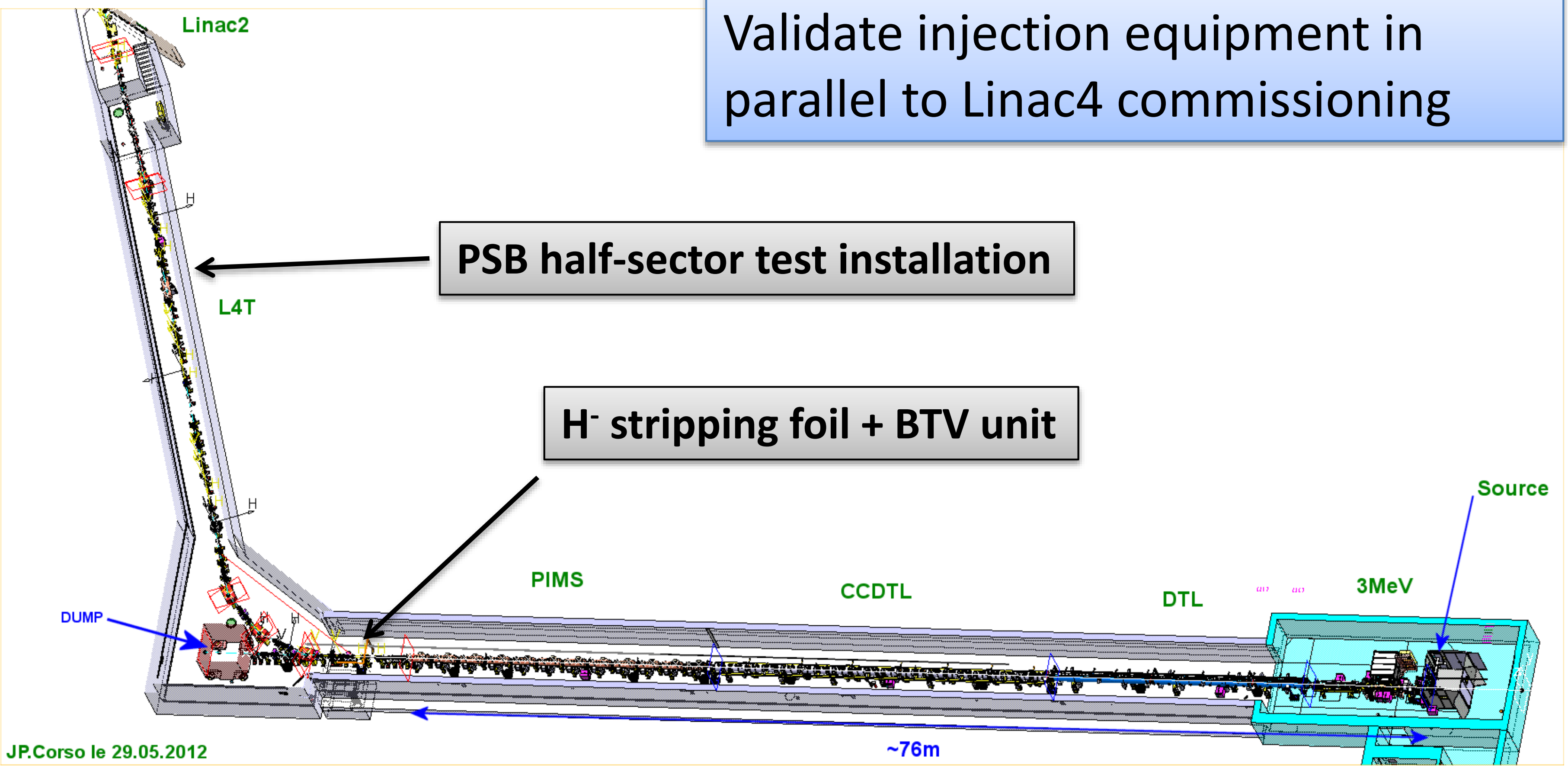




Emittance preservation in the PSB , E. Benedetto

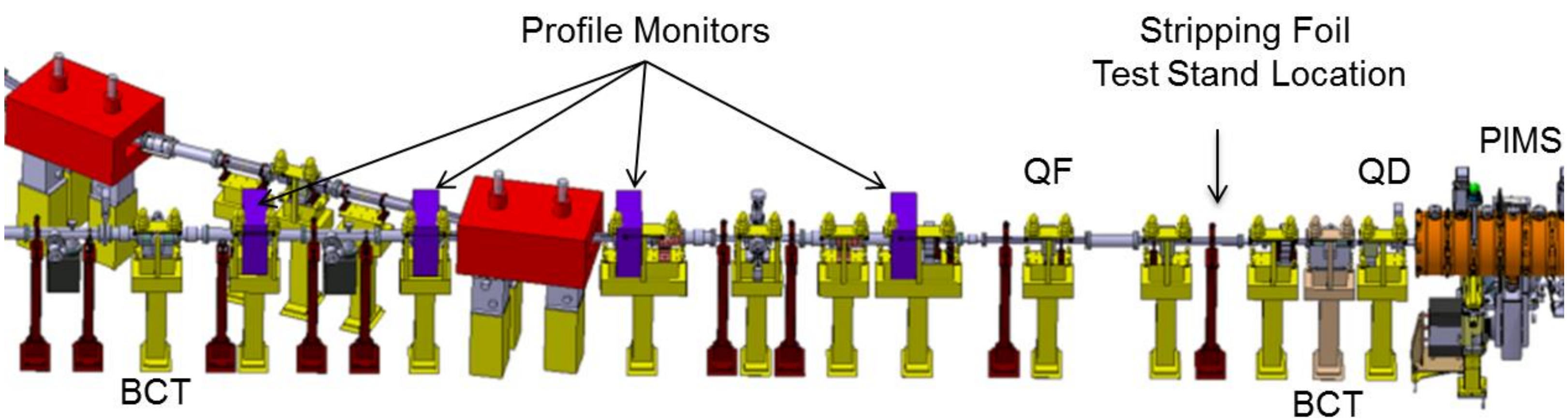
Test stand

Validate injection equipment in parallel to Linac4 commissioning



Foil stripping test stand

- Foil handling and exchange mechanism, controls, interlocks
- Instrumenation
- Stripping efficiency for different foils with current transformers
- Emittance growth from profile monitors
- Permanent installation – autumn 2015

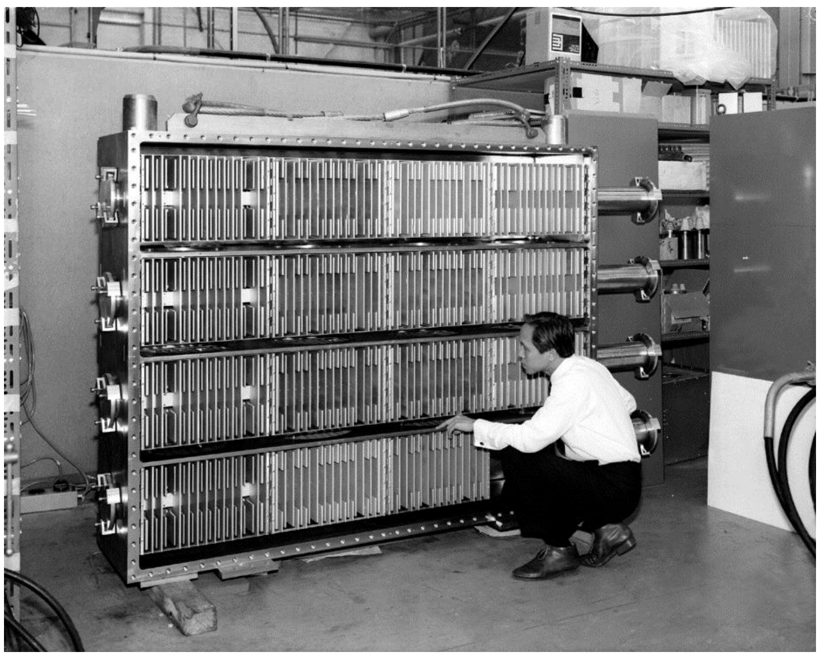


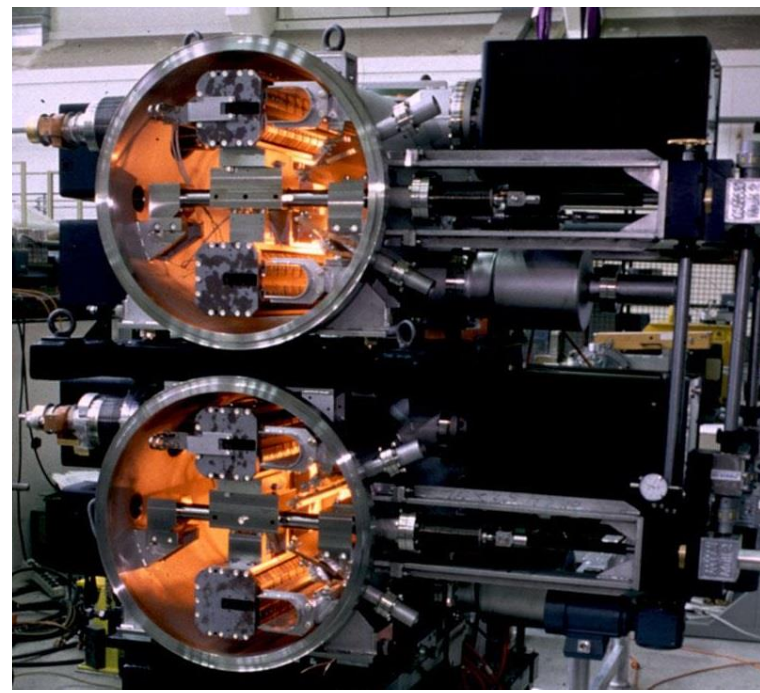
Half sector test - 2016

- Temporary installation of half the chicane with stripping foil unit, H^0H^- monitor and dump
- Additional tests
  - Chicane
    - Powering and control of half of the chicane magnets
    - Current stability and interlocking
  - Stripping foil
    - More precise stripping efficiency measurement of H^0 and H^-
    - Interlocking of foil position
  - H^0/H^- dump
    - Aperture check
    - Temperature cross-check with simulated values
    - Interlocking (temperature and pressure drop – define operational thresholds

PSB extraction

- PSB extraction bumpers → OK with present system
- PSB extraction kickers → on the limit – to be measured which field can be reached in ferrites
- PSB extraction septa: bus bars to be reinforced, magnets to be cooled in parallel to deal with increased RMS current



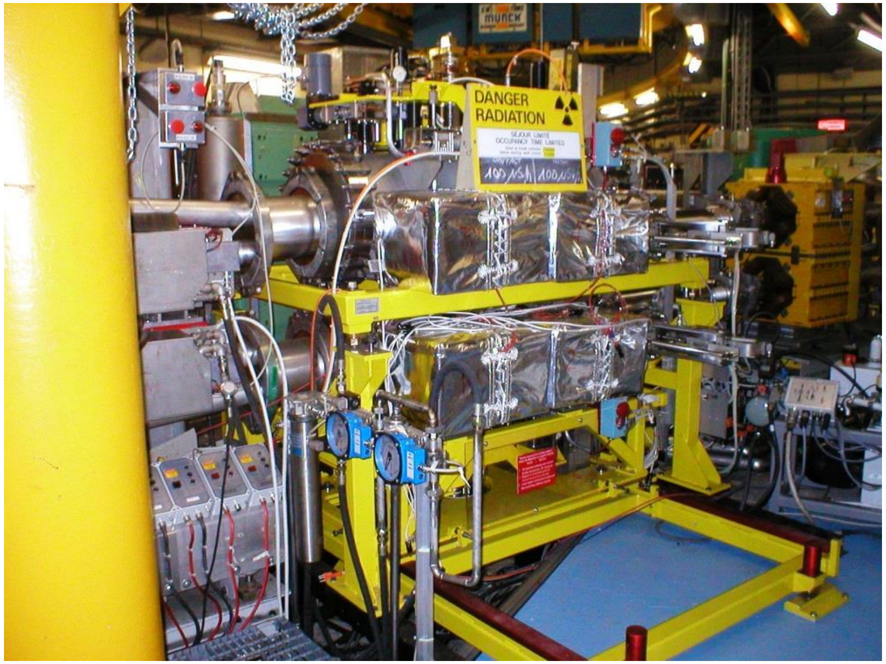


Aim of the PSB-PS transfer upgrade

- All beams to be transferred at 1.4 and 2 GeV
  - Magnet strength increased by 30% ($B\rho_{2GeV} / B\rho_{1.4GeV}$)
- Match optics at PS injection to reduce emittance blow-up due to dispersion mismatch
  - Horizontal dispersion is presently not matched; install one additional quadrupole in BTP line to match the line to the PS injection optics
  - Vertical dispersion remains mismatched due to the vertical displacement of the four PSB rings ($D_y < 0.5$ m)
- Optimise optics for different beams
  - Requires pulse-to-pulse modulation capability of hardware

Recombination Septa

- BT recombination septa:
  - new magnets (from 1060 to 1300 mm) to be inserted into existing vacuum vessel
  - BI equipment to be moved outside vessel to provide space for longer magnets
  - Baseline accepts vacuum degradation (longer magnet,but smaller laminations)

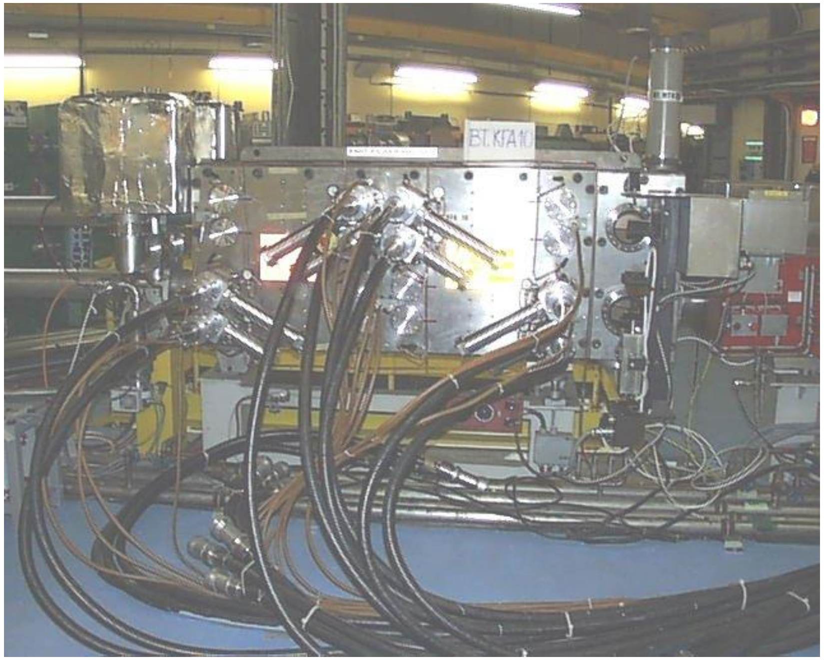


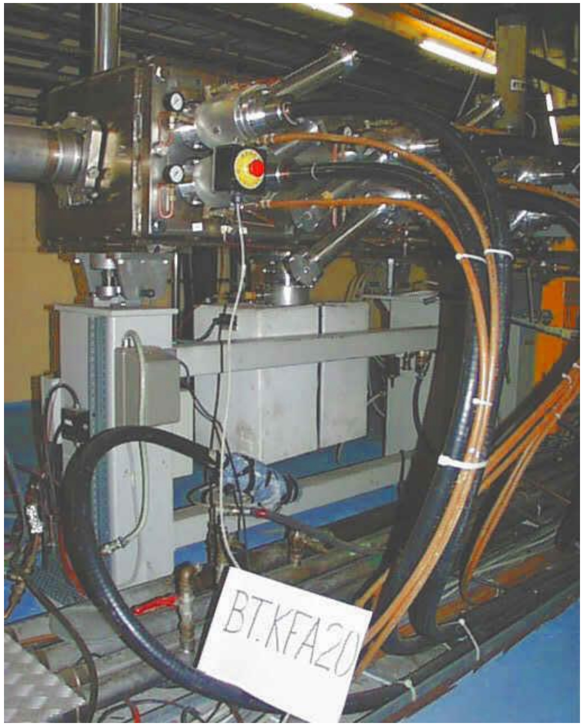
Upgrade of CERN PSB Recombination, J. Abelleira, Poster

- Aperture increase will not improve beam acceptance
- Allows to build longer magnets with same cross section

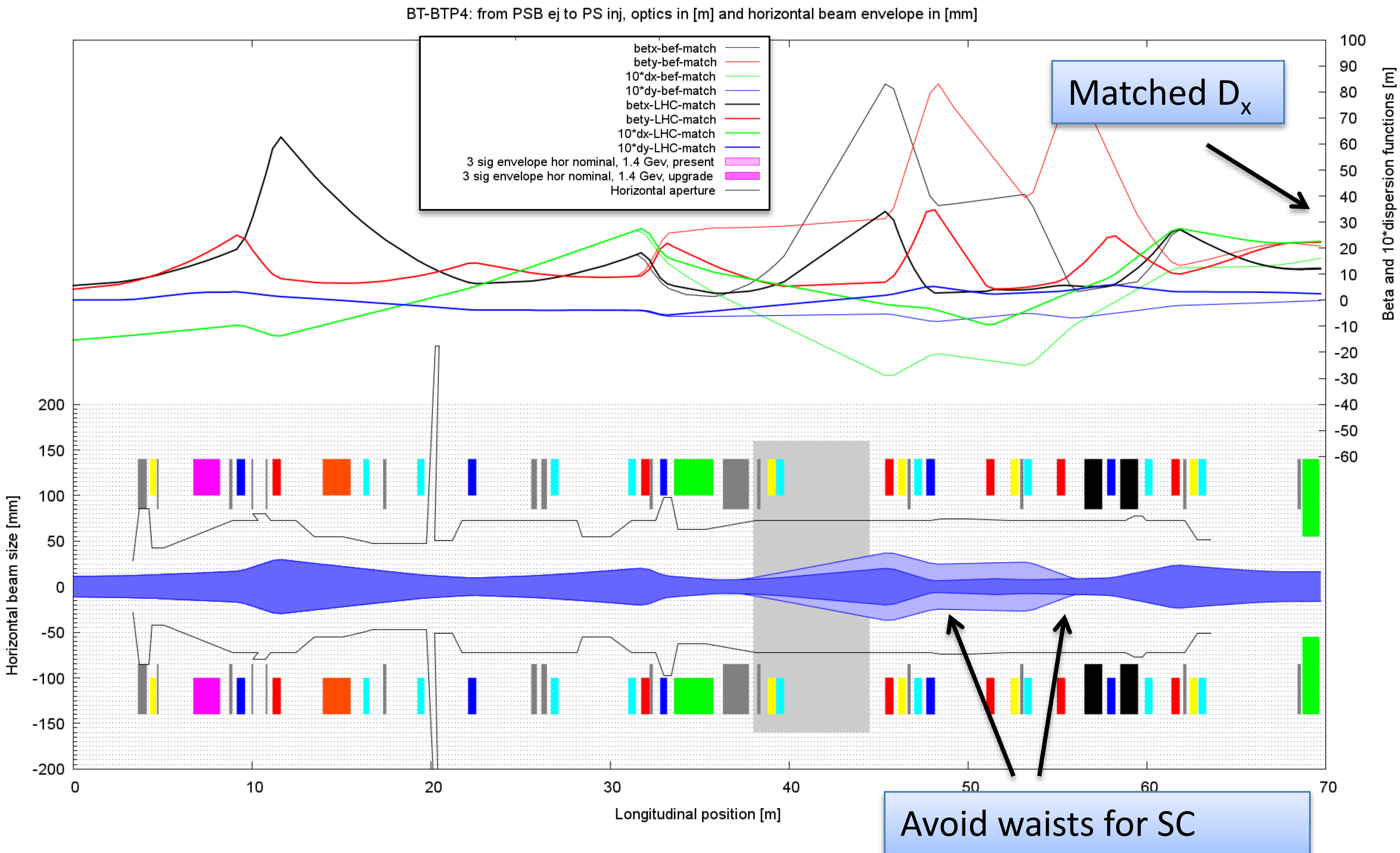
Recombination Kickers

- BT recombination kicker
  - 202 mT required vs 200 mT max in the KFA10 ferrite
  - Ferrite replacement for vacuum peformance

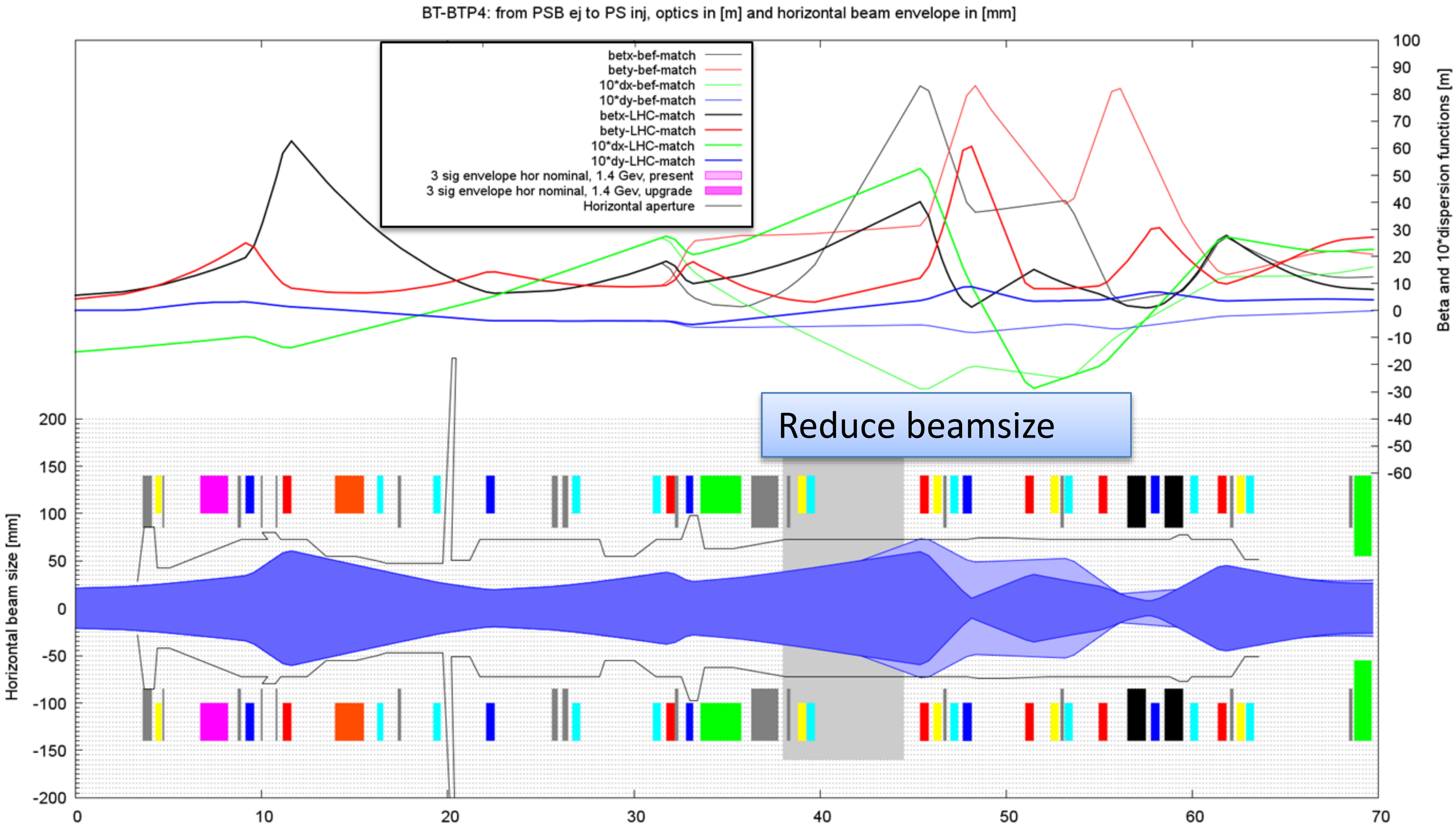




Transfer optics for LHC beams

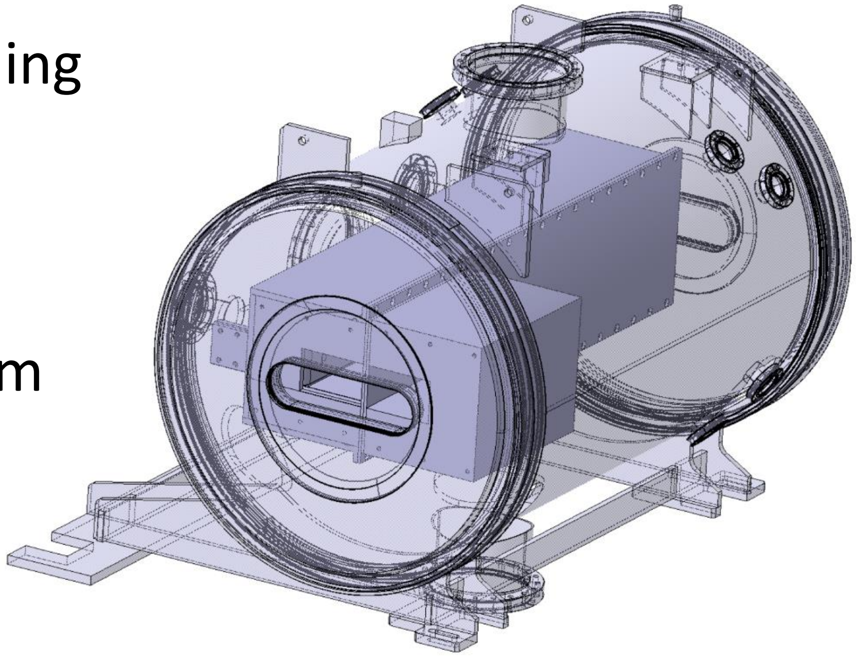


Transfer optics for HI beams



PS injection - Septum

- 30% increase of B.dl by lengthening magnets
- Bumper integrated
  under vacuum next to the septum
- Both of eddy current type
  - Robust
  - Need careful design of pulse shape
  - Evaluating higher order components wrt distance from blade and time

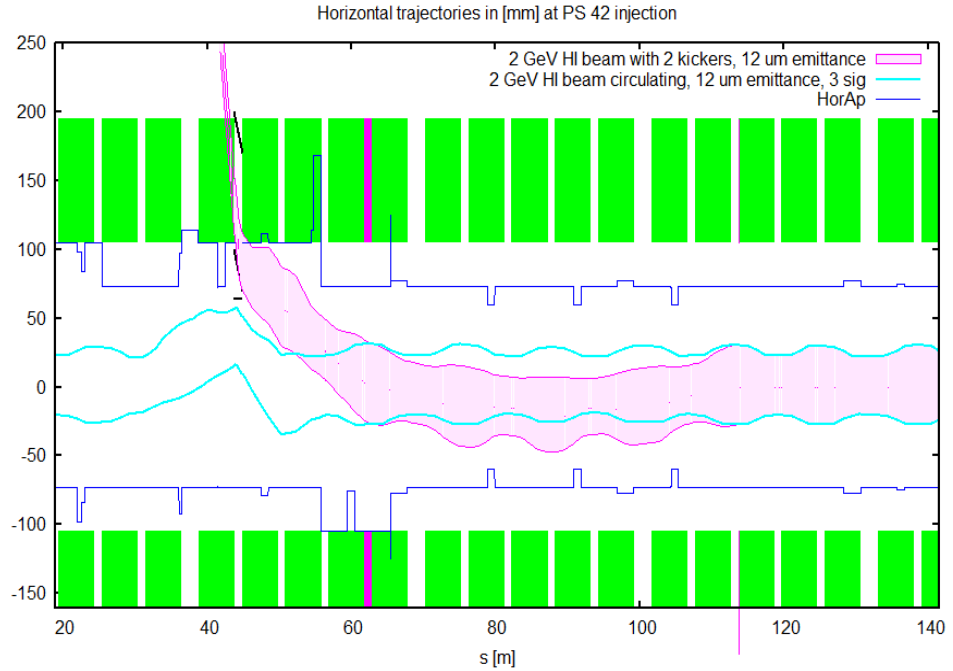


PS injection - Kicker

- 4 modules of travelling wave kicker which can be terminated or short-circuited

- Need to rebuild the system since there is no spare

- Existing specification of rise/fall times requires to build an additional injection kicker system in the PS – impedance!

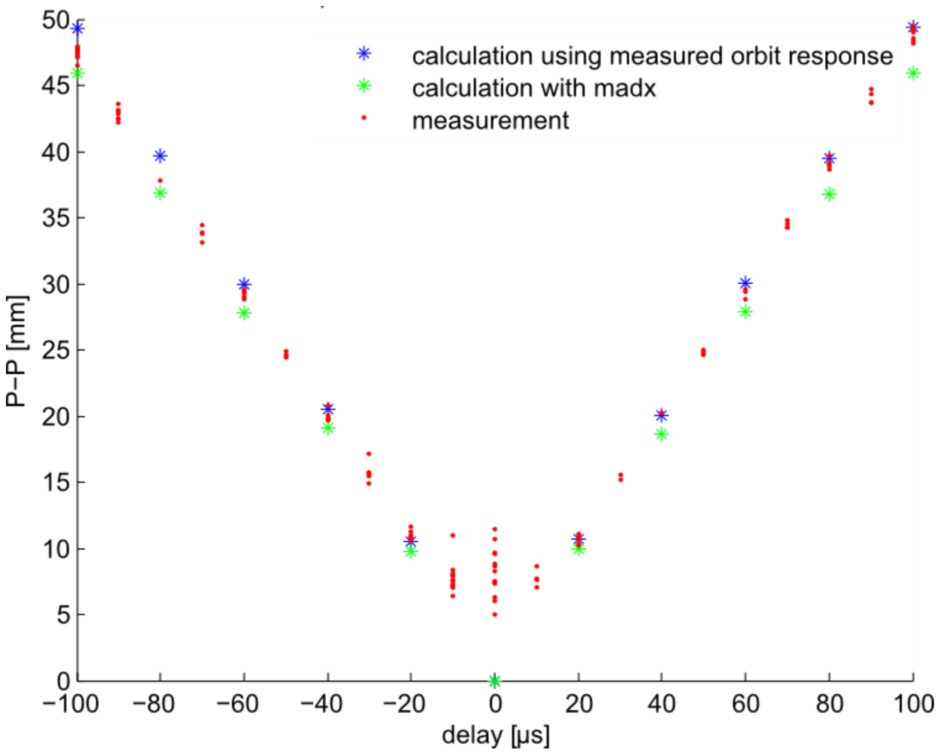


PS injection - Kicker

- Present and future beam production can live with longer rise times than present 46 ns
- Aim at avoiding a second kicker system due to impedance and complexity
  - *Effect of impedance shielding on rise time difficult to quantify*
- Present system uses SF6 gas filled cables (80 kV) which are difficult to procure → conventional cables (40 kV)

PS injection - bump

- Synchronisation of inside vacuum eddy current bumper bumper with existing bumpers



Summary

- HL-LHC goals require **increased brightness** from injectors
- Incoherent SC tune shift reduced by **increased injection energies** in PSB (50 →160 MeV) and PS (1.4 → 2 GeV)
- PSB charge exchange injection should significantly **reduce** the present 40% **beam loss at injection** and give better flexibility for transverse painting
- Modified quadrupole structure in transfer line allows for **improved optics matching of LHC** beams and increased **acceptance of HI beams**
- **Technological challenges** at PS injection: large aperture eddy current septa, kicker impedance, bumper synchronisation

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- Modified quadrupole structure in transfer line allows for **improved optics matchi** **acceptance of HI beams**
- **Technological challenge** current septa, kicker impedance, bumper synchronisation

Thank you for your attention!