# Review on PS Booster with L4

## Upgrade of Distribution and Injection Region

Wim Weterings TE/ABT

Thanks to many colleagues for their contribution, in particular:

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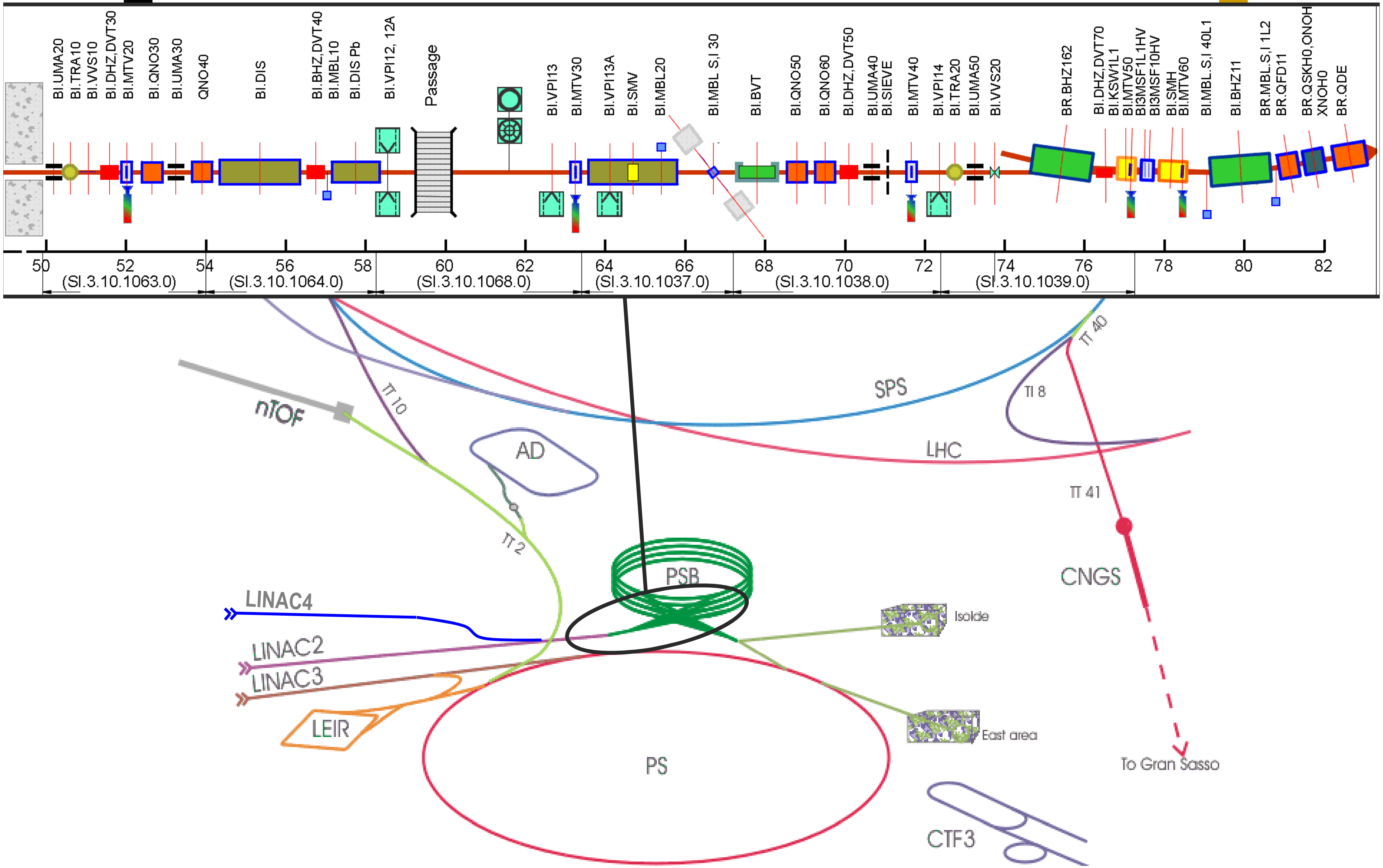
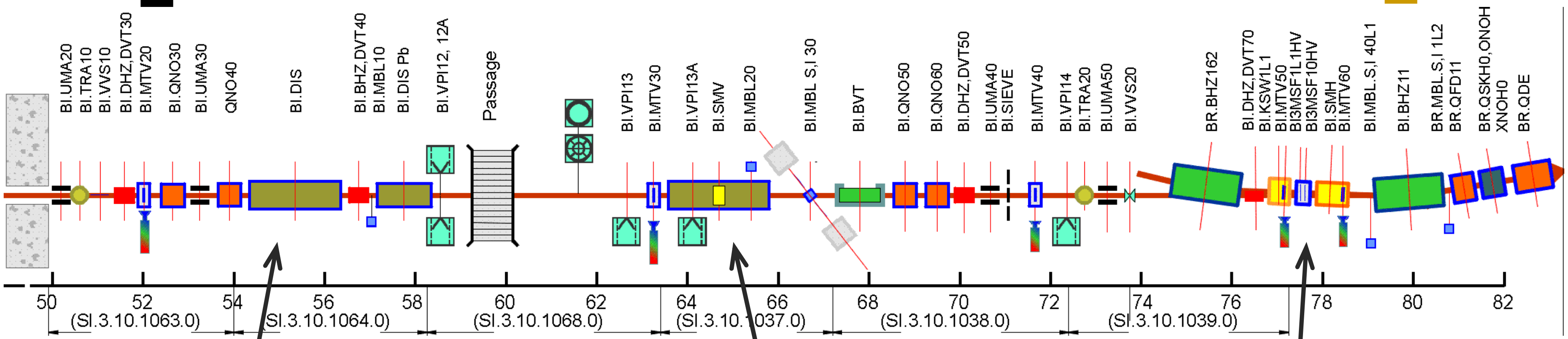
# Talk Overview

- *Beam Separation Principle*
  - *Required Modifications*
  - *Beam Distribution (BI.DIS)*
  - *LINAC4 Pulse Structure*
  - *Beam Separation (BI.SMV)*
- *$H^-$ charge-exchange Injection System*
  - *Principle*
  - *Status*
  - *Layout and Available Space*
- *Main Design Parameters*
- *Present Status*
- *Conclusion*

# Booster Injection Principle

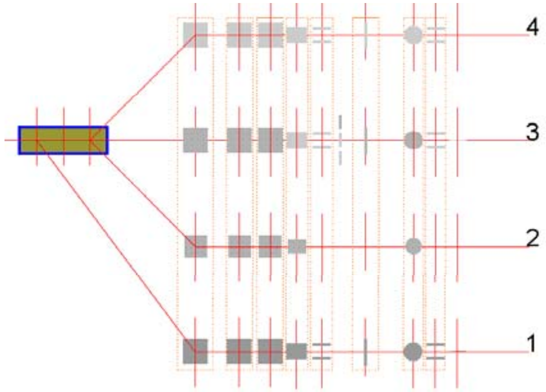


# Booster Injection Principle



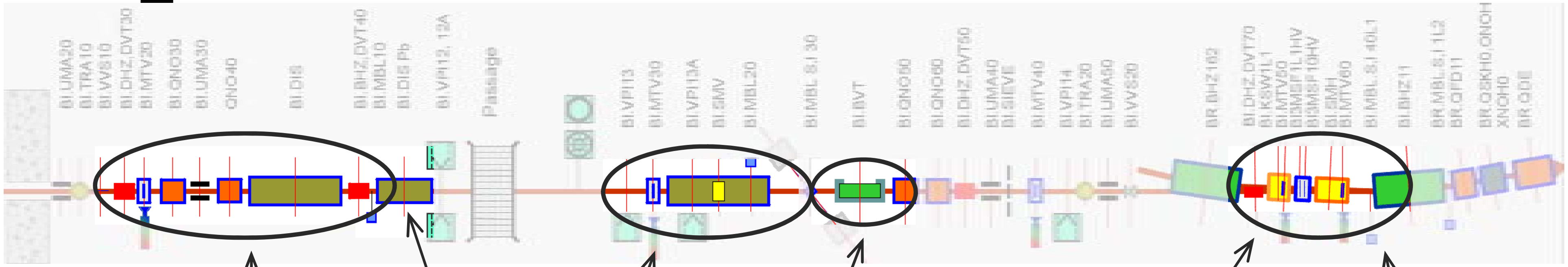

**Proton Distributor BI.DIS**
system of pulsed magnets, which kick slices of the beam to different vertical positions at the vertical septum BI.SMV

**Vertical Septum BI.SMV & BI.BVT**
Beam slices are further deflected by the BI.SMV septa into the BI.BVT vertical dipole apertures to achieve the required booster beam level separation of 360 mm between each ring




**$H^-$ Charge-Exchange Injection System**
160 MeV $H^-$ beam from LINAC4 is injected through a graphite stripping foil to convert ~98% of the beam to protons, using two independent closed orbit bump systems

# Required Modifications for LINAC 4



Remove obsolete BI.DIS Pb

Modify BI.DIS for 4.3 mrad @ 160 MeV

Performance increase of 1.9 in ∫B•dl of BI.DVT30, BI.QNO30, BI.QNO40, BI.DVT40.

New BI.SMV, 4 mm thick septum and 70 mm horizontal aperture for ~165 mrad @ 160 MeV with associated new pulse generator.

~0.36 Tm required from BI.BVT for ~175 mrad @ 160 MeV

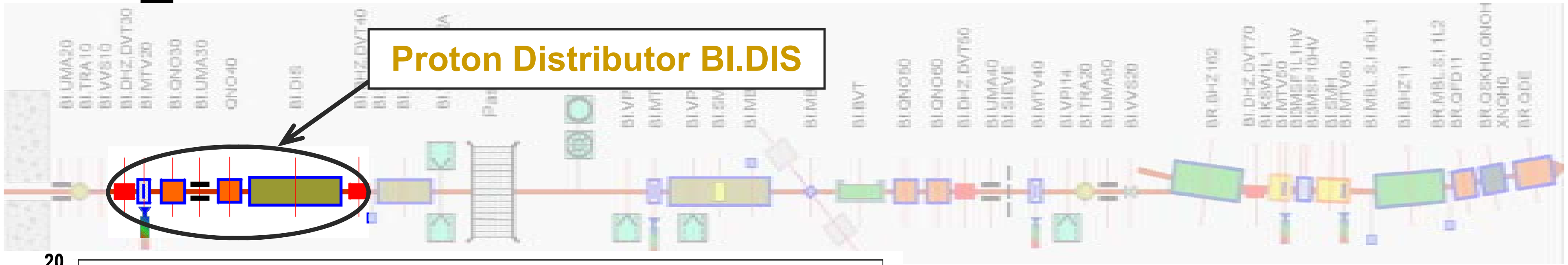
Relocate modified KSW1L1 magnet to PSB period 16, build new pulse generator.

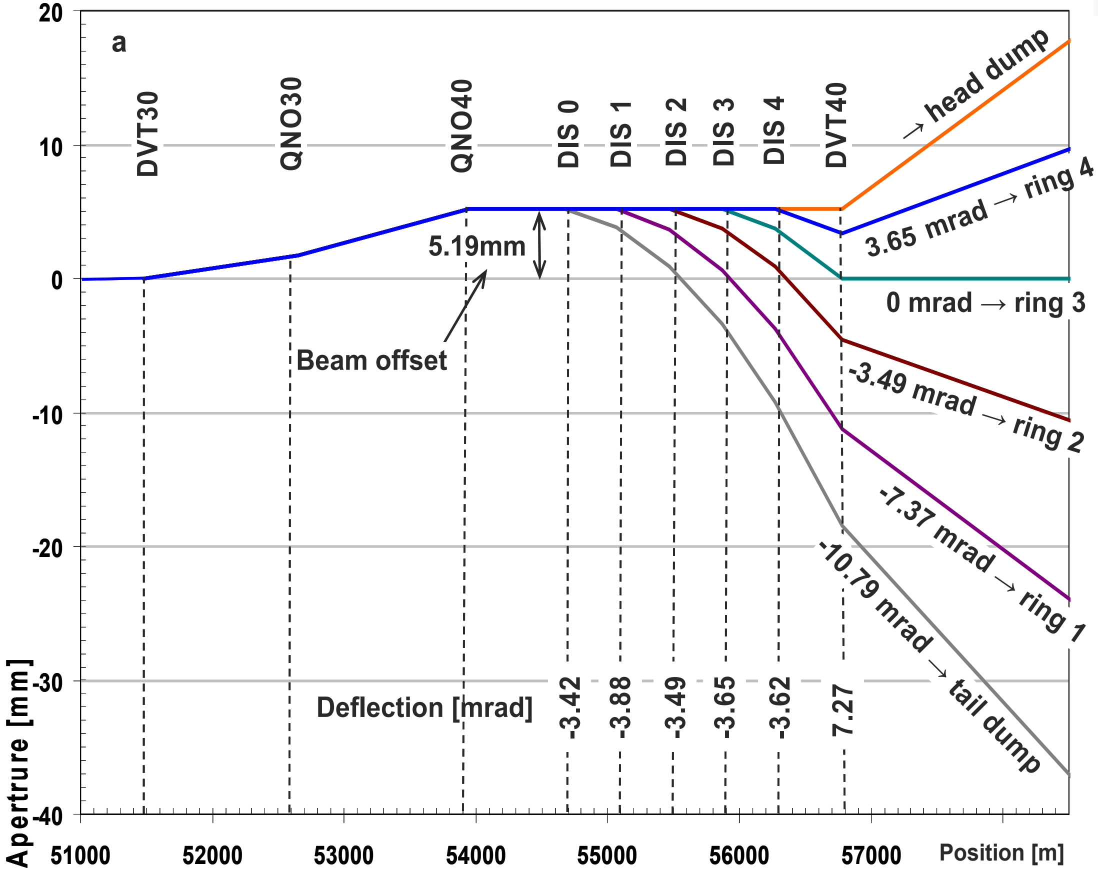
Rebuild the 2.654 m injection region of each of the 4 PSB rings:

- 4 new BS magnets,
- Foil holder and handler,
- Dump for unstripped $H^0/H^-$,
- Beam Instrumentation.

# Booster Injection Principle

## Beam Distribution

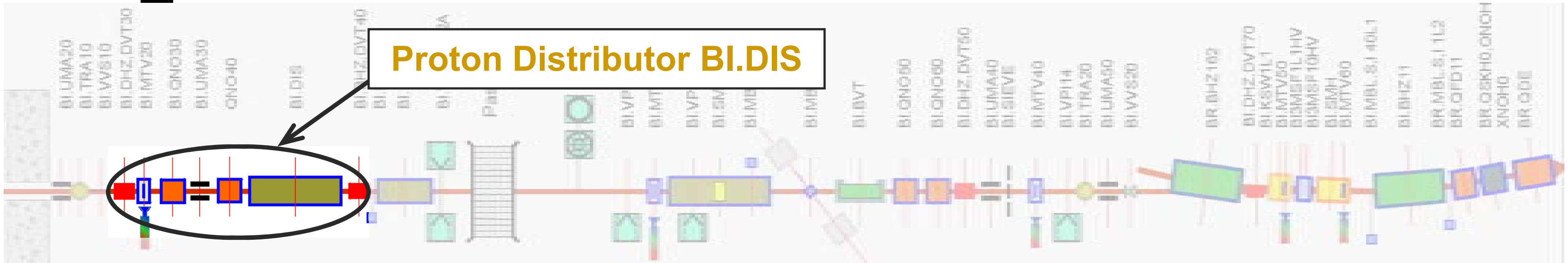


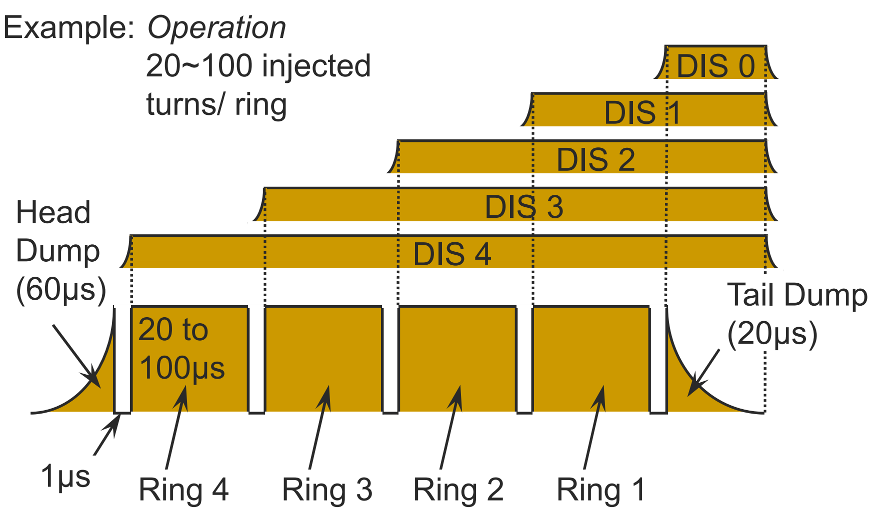

- *LINAC4 beam enters the BI.DIS with a ~5.2 mm vertical offset.*
- *The BI.DIS system, in combination with BI.DVT40, kicks slices of the beam into the septa BI.SMV.*
- *a ~3.5 mrad deflection producing a vertical beam separation of 35 mm at the BI.SMV.*
- *In case of BI.DIS failure, the full beam is deflected by BI.DVT40 into an absorber block (head-dump).*

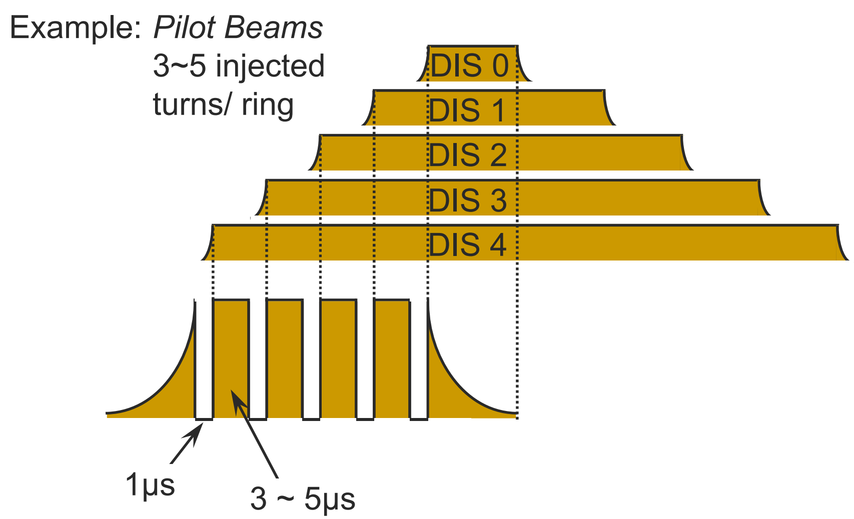
# Booster Injection Principle

## LINAC4 Pulse Structure



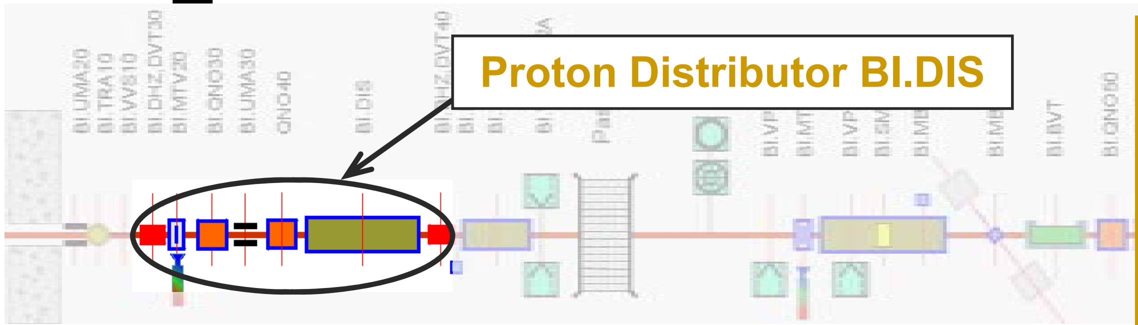

- *4 individual LINAC4 pulses, typically 20~100µs long with 1µs gap for BI.DIS rise-time.*
- *Fixed BI.DIS pulse lengths, but different for each magnet.*
- *Timing to be adjusted according to required number of injection turns from pulse to pulse.*



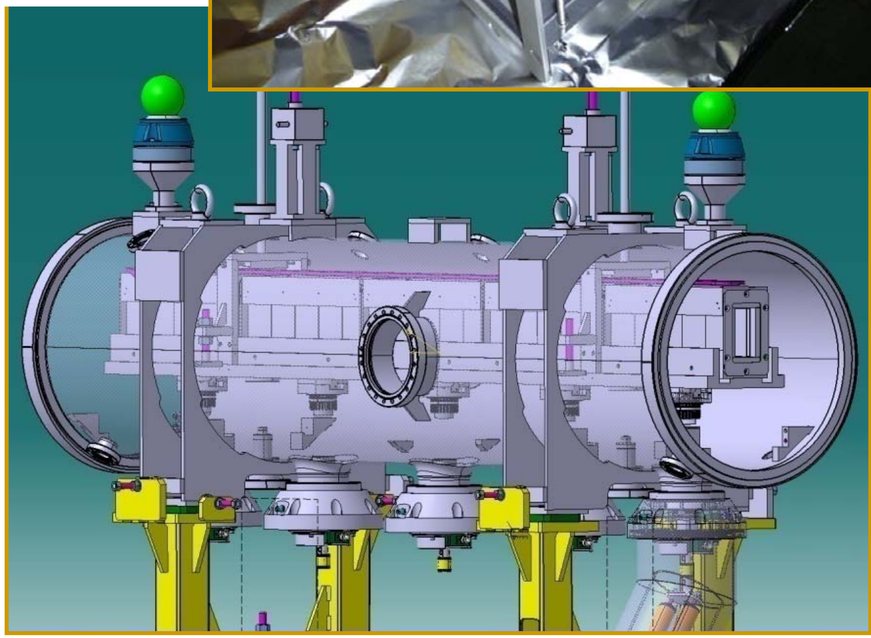



# Booster Injection Principle

Status



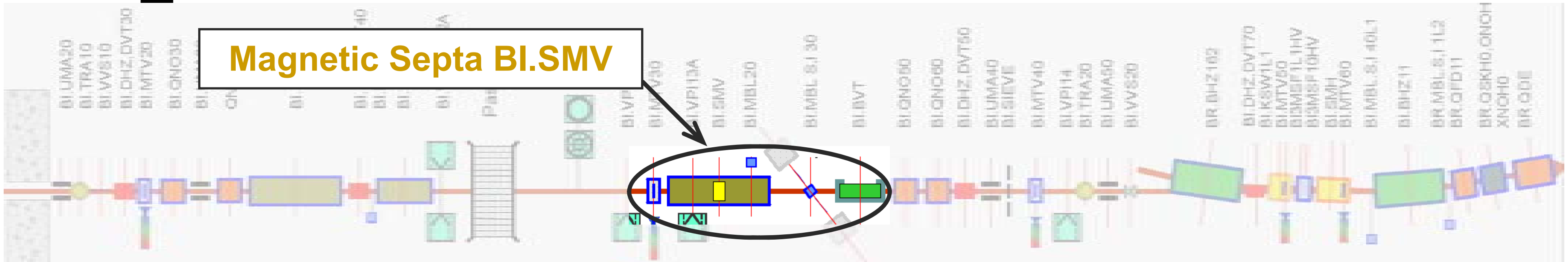

- *Magnet design optimised,*
- *Vacuum vessel designed and ordered for April 2009*
- *Ferrite blocks delivered for all magnets,*
- *prototype coil & magnet built,*
- *Mechanical supports delivered,*
- *Custom current transformers delivered,*

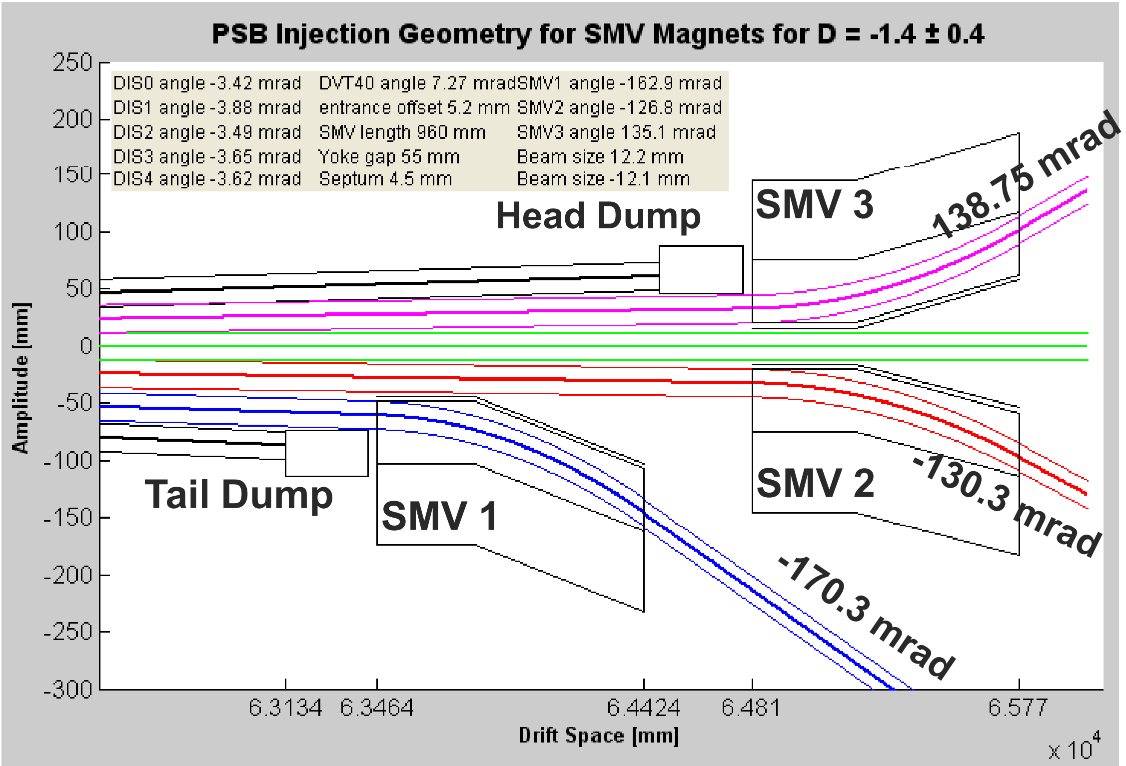


- *HV and magnetic tests imminent,*
- *HV feedthrough under study,*
- *Limited space available for magnet protection elements,*
- *Planned to have 2 operational BI.DIS by end 2009*

# Booster Injection Principle

## Beam Separation

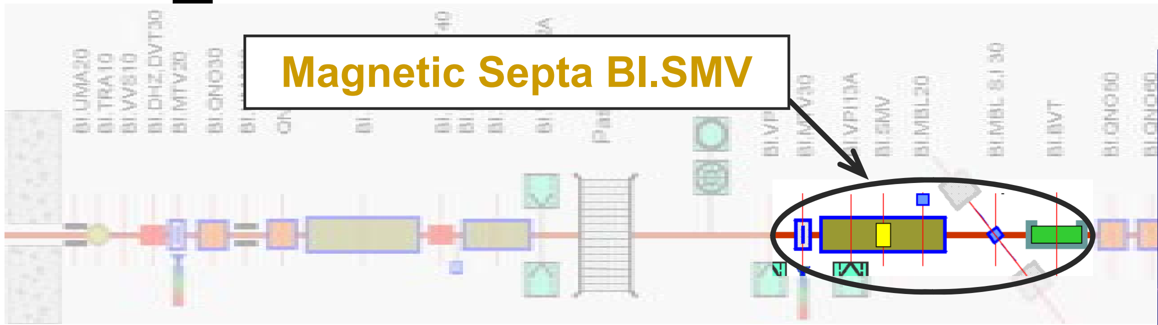


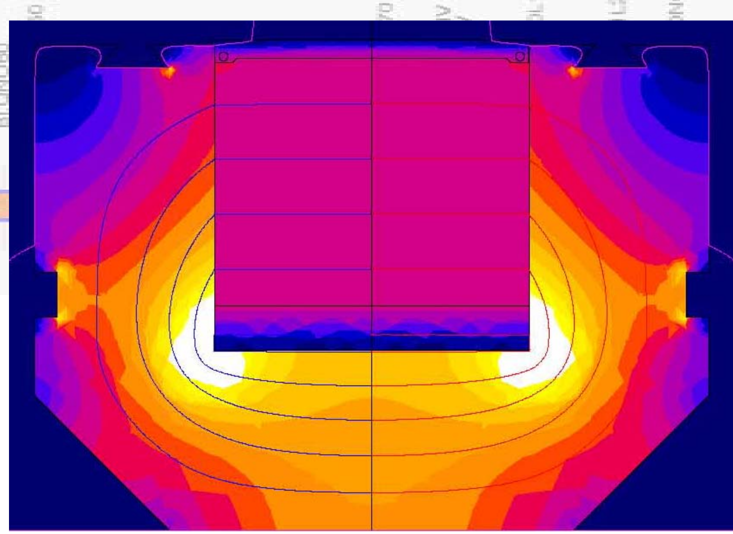




- *The rising edge of the LINAC4 pulse is deflected to a absorber block (head dump).*
- *BI.SMV septa deflect the beam vertically into apertures of 3 separate BI.BVT vertical dipole magnets to achieve the required PSB beam level separation of 360 mm between each ring.*
- *Beam designated for ring 3 will see no magnetic field and passes between SMV2 and SMV3.*
- *The falling edge of the LINAC4 pulse is deflected to a second absorber block (tail dump).*

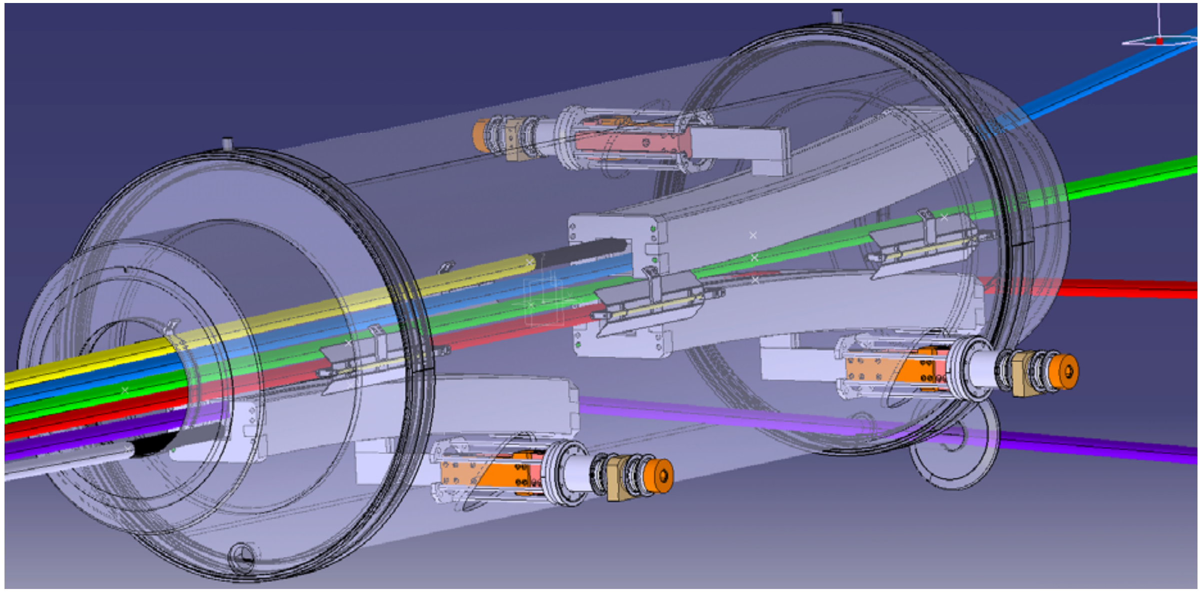
# Booster Injection Principle

Status

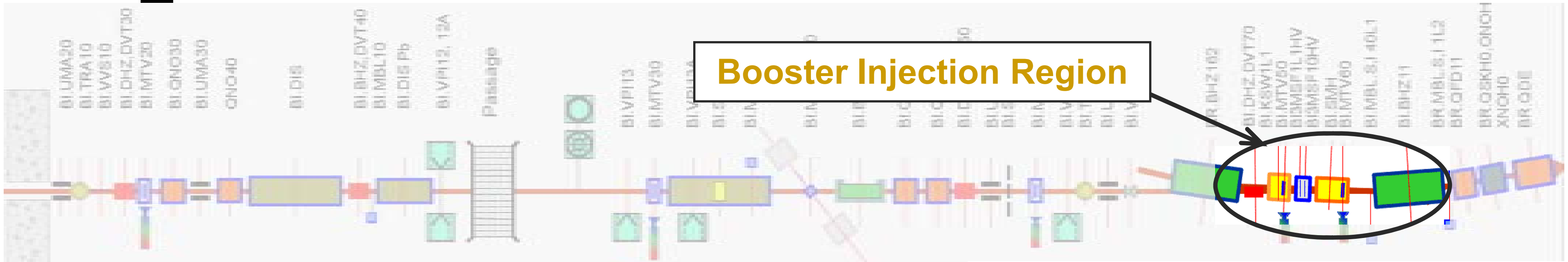


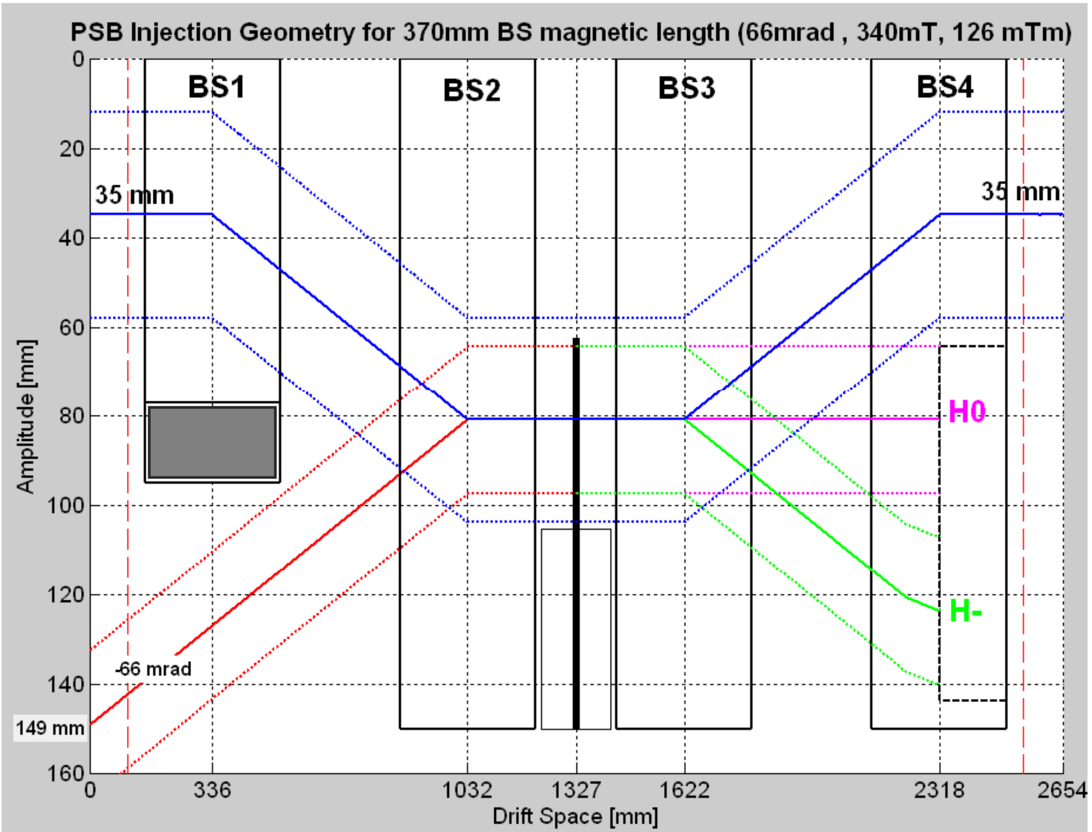



- *Magnet cross-section designed,*
- *Vacuum vessel and magnet layout under study,*
- *Curved laminated yoke technology to be validated spring 2009,*
- *Yoke forming tool ordered,*
- *Head and Tail dump loading specified (EDMS963395)*
- *Magnet parameters & design to be completed summer 2009.*
- *Constraint: In case of a chopper failure, beam will be swept across BI.SMV septa blades.*



# $H^-$ Injection System

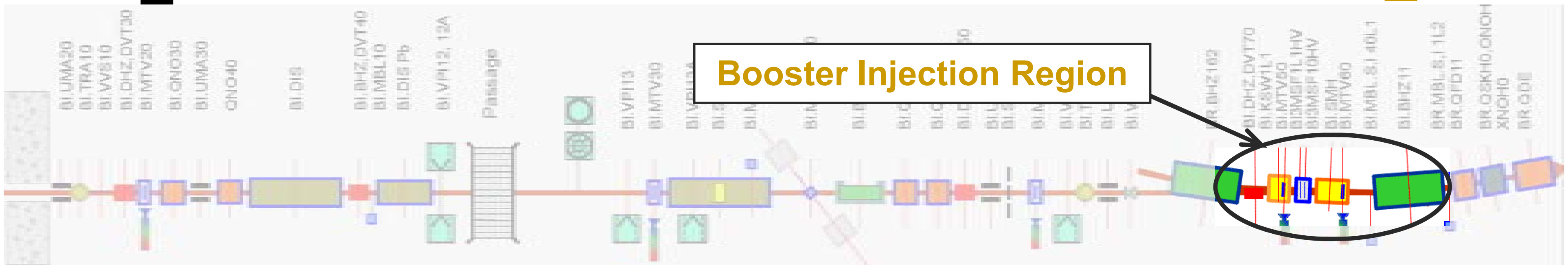



- *Two independent closed orbit bump systems:*
  - *Injection Chicane, 4 pulsed dipole magnets (BS), located in the injection region, giving 45 mm beam offset during the injection process.*
  - *Painting Bump, 4 horizontal kickers (KSW), outside the injection region, giving 35 mm closed orbit bump with falling amplitude for transverse phase space painting.*
- *Injected beam with -10mm horizontal offset.*
- *BS1 must act as septum.*
- *BS4 should accommodate internal Dump.*
- *Stripping efficiency of ~98% expected.*

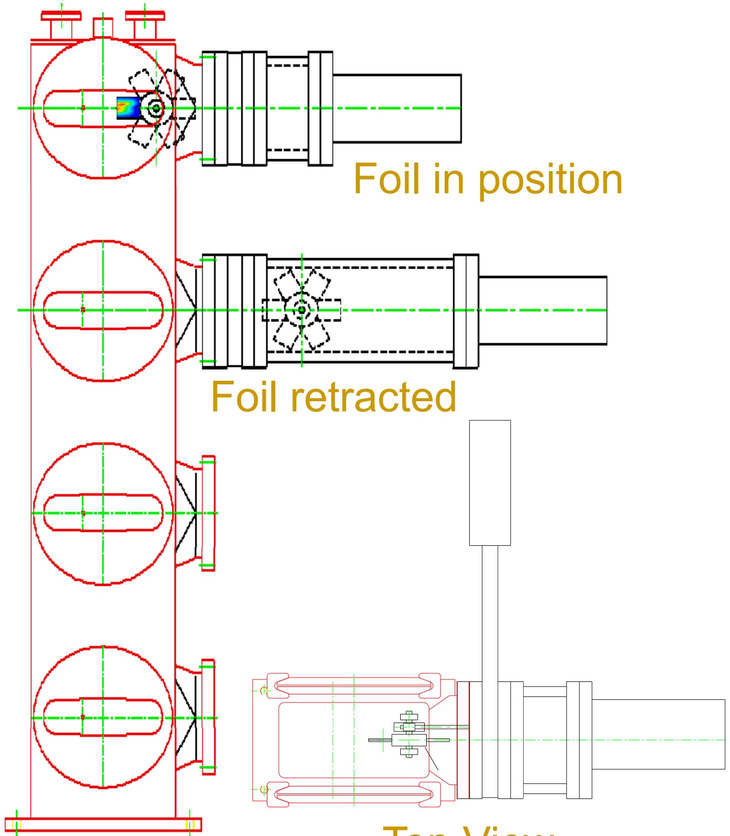
# Booster Injection Principle



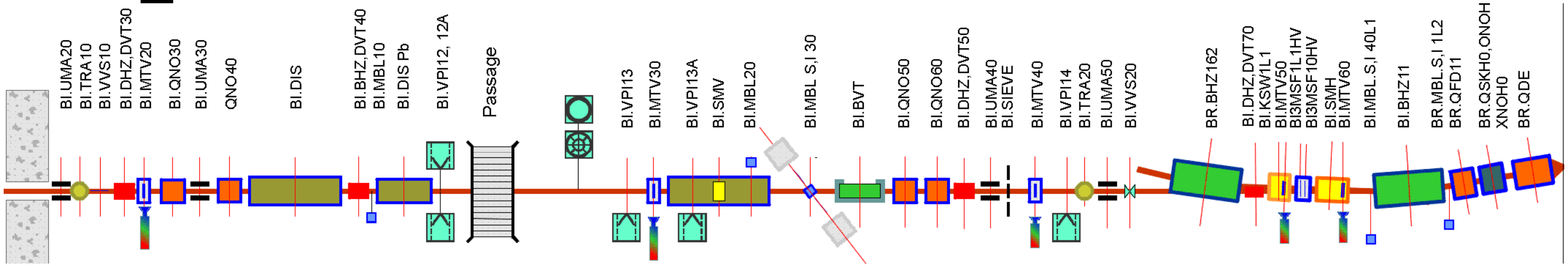


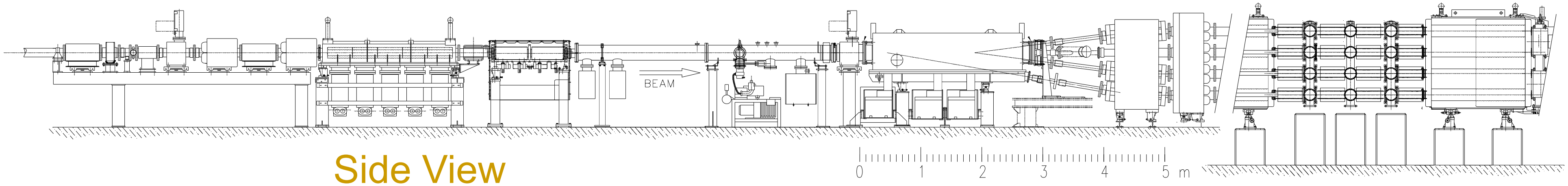

- *Outside vacuum magnet design under investigation (vs inside vacuum baseline design),*
- *Chicane fall time increased (ms range)*
- *Undulated inconel chambers to be used,*
- *Modified alternative magnet design to reduce lattice perturbations being studied,*
- *BS1 will use direct drive septum geometry,*
- *Injection concept to be finalised summer 2009,*
- *Stripping foil carousel under study,*
- *$H^0$ / $H^-$ dump integrated in BS4 magnet, expected load specified in EDMS963395 (see table).*

| | Load [W] | Activation [$p^+$/y] | Energy @ failure [kJ] |
|---|---|---|---|
| Head Dump | 213 | $1.44 \cdot 10^{20}$ | 2 ($1.0 \cdot 10^{14} p^+$@160$MeV$) |
| Tail Dump | 71 | $4.8 \cdot 10^{19}$ | 2 ($1.0 \cdot 10^{14} p^+$@160$MeV$) |
| $H^0/H^-$ dump | 14.2 | $1.04 \cdot 10^{19}$ | 2 ($1.0 \cdot 10^{14} p^+$@160$MeV$) |

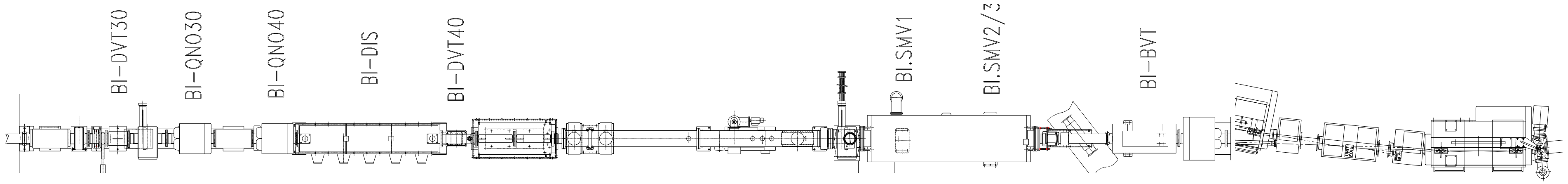


# Layout and Available Space



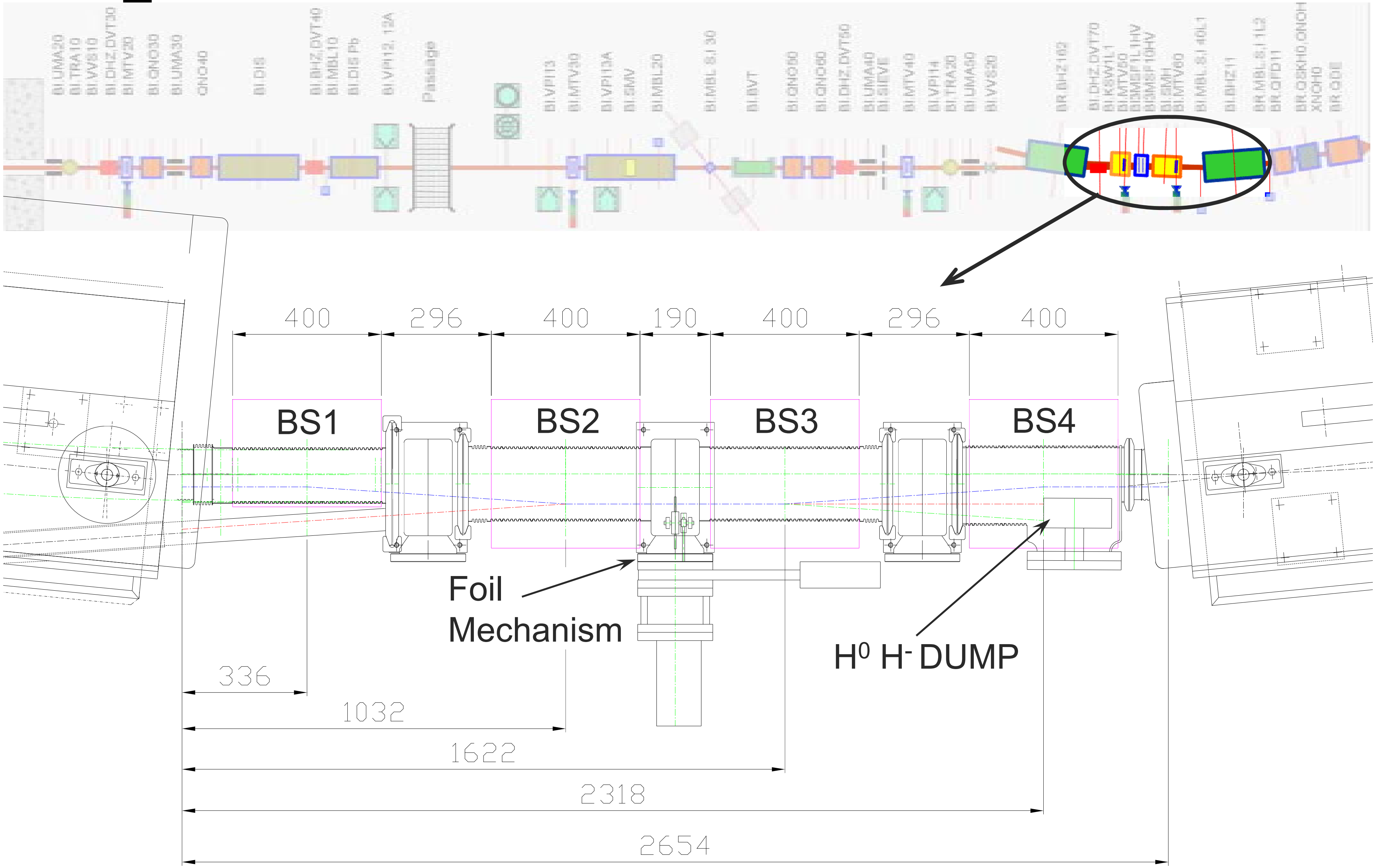




Side View

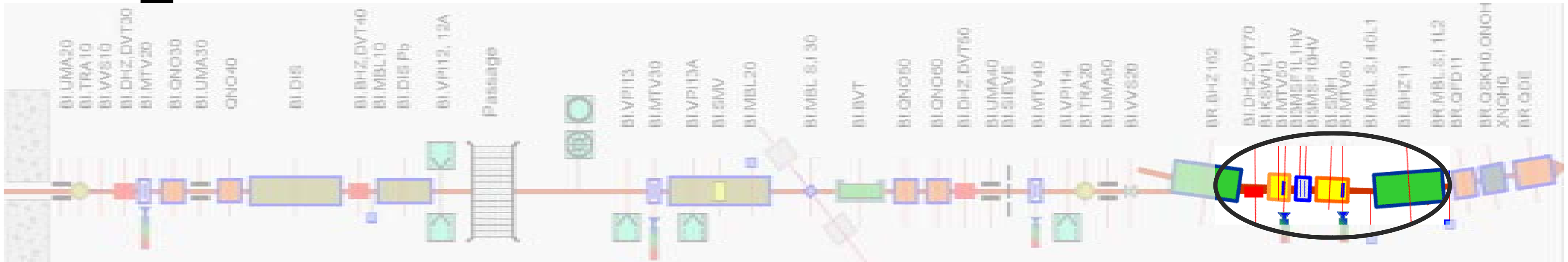


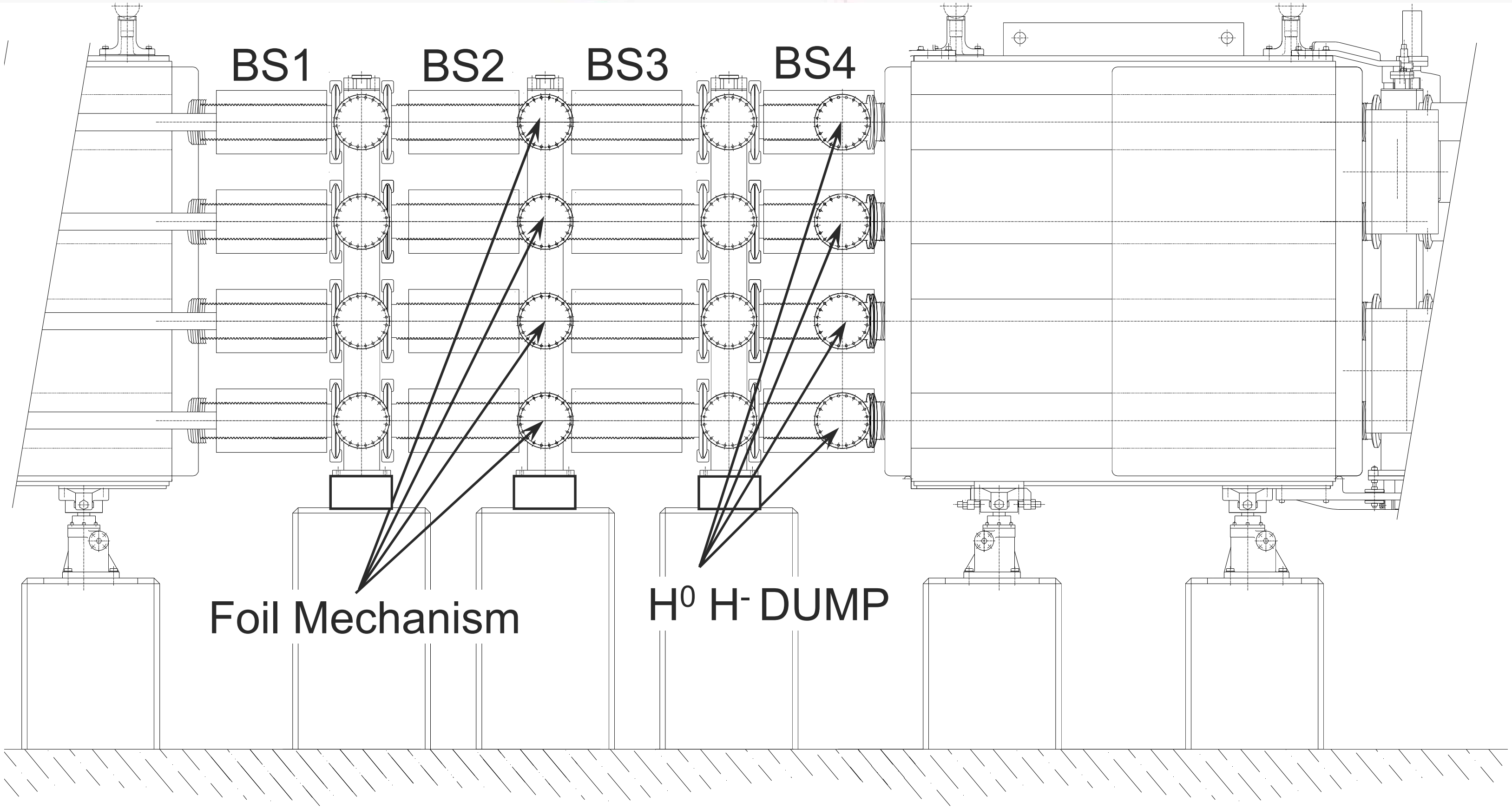

Top View

# Layout and Available Space



# Layout and Available Space





# Main Design Parameters

| | | BI.DIS | BI.SMV | BS |
|---|---|---|---|---|
| Deflection angle | mrad | 4.3 | 170 | 66 |
| Integrated field | mTm | 8.2 | 324 | 126 |
| Gap field | mT | 23.1 | 337 | 340 |
| Vertical beam acceptance | mm | 98 | 32 | 62 |
| Gap width | mm | 50 | 70 | 130 |
| Magnetic length | Mm | 354 | 960 | 370 |
| Peak current | kA | 0.95 | 18.3 | 10.9 |
| Magnet inductance | μH | 0.9 | 1.3 | 3.6 |
| Magnet resistance | mΩ | 0.03 | 0.1 | 0.08 |
| Number of turns | | 1 | 1 | 2 |
| Repetition rate | Hz | 1.11 | 1.11 | 1.11 |
| Rise / Fall time | | 1 μs | | ~3 ms |
| Flat Top duration | | 420 μs | 100 μs | ~2 ms |

# Conclusions

- *In order to distribute and inject the 160 MeV beam from LINAC4 into the four rings of the PSB, new distributor magnets and magnetic septa with a performance increase of 1.9 in ∫B·dl need to be built.*
- *The pulse structure from LINAC4 will consist of 4 individual pulses, typically 65-100 μs long. The distributor pulse length will be fixed, but different for each magnet.*
- *A completely new $H^-$ charge-exchange injection needs to be built comprising four injection dipole magnets, a stripping foil unit, an internal beam dump, and suitable instrumentation.*

# Present Status

- *BI.DIS*
  - *Design of new vacuum vessel completed.*
  - *Prototype magnet built.*
  - *Ferrite blocks, mechanical supports & custom current transformers delivered.*
  - *2 operational BI.DIS by end 2009.*
  - *Currently 'scrapers' installed, in new design only limited space available (collimation in line...).*
- *BI.SMV*
  - *Magnet cross-section design completed.*
  - *Vacuum vessel and magnet layout under study.*
  - *Magnet yoke forming tool ordered.*
  - *Head &Tail dump loading specified (EDMS963395), impact to be studied.*
  - *Yoke curving technology to be validated.*
  - *Horizontal aperture <70mm to be studied.*

# Present Status

- *BS* — *- Basic prototype has been tested to validate OPERA™ simulations.*
  *- Outside vacuum magnet design, using undulated inconel chambers, is being studied.*
  *- Alternative magnet design to reduce lattice perturbations.*
- *Foil Unit* — *- Nuclear foil physics effects are being studied.*
  *- Stripping foil carousel under study.*
  *- Prototype planned for autumn 2009.*
- *$H^o/H^-$ Dump*
  *- Expected loading specified (EDMS963395)*
  *- Thermo-mechanical studies being prepared.*
  *- H0 / H- dump integrated in BS4 magnet.*