LINAC4 ADVISORY COMMITTEE

Booster Injection Modification

Wim Weterings AB/BT

With input from

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and many others

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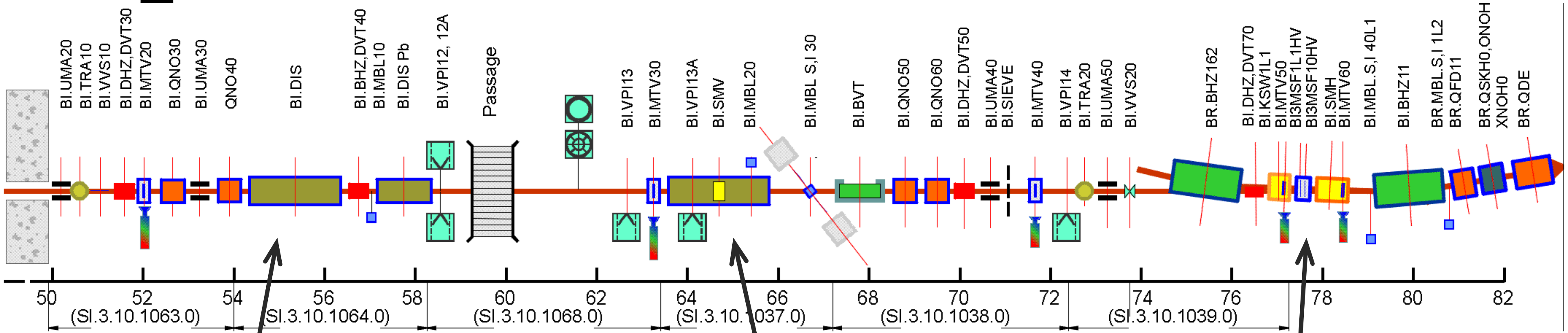
Talk Overview

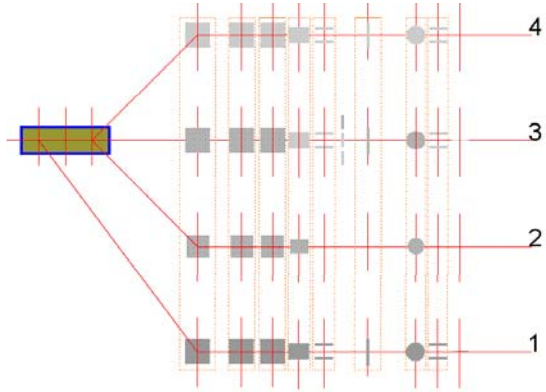
- *Booster Injection Principle*
  - *Beam Distribution*
  - *LINAC4 Pulse Structure*
  - *Beam Separation*
- *H^- charge-exchange Injection System*
  - *Principle*
  - *Foil Heating*
- *Layout and Available Space*
- *Required Modifications*
- *Main Design Parameters*
- *Present Status*
- *Conclusion*

Booster Injection Principle



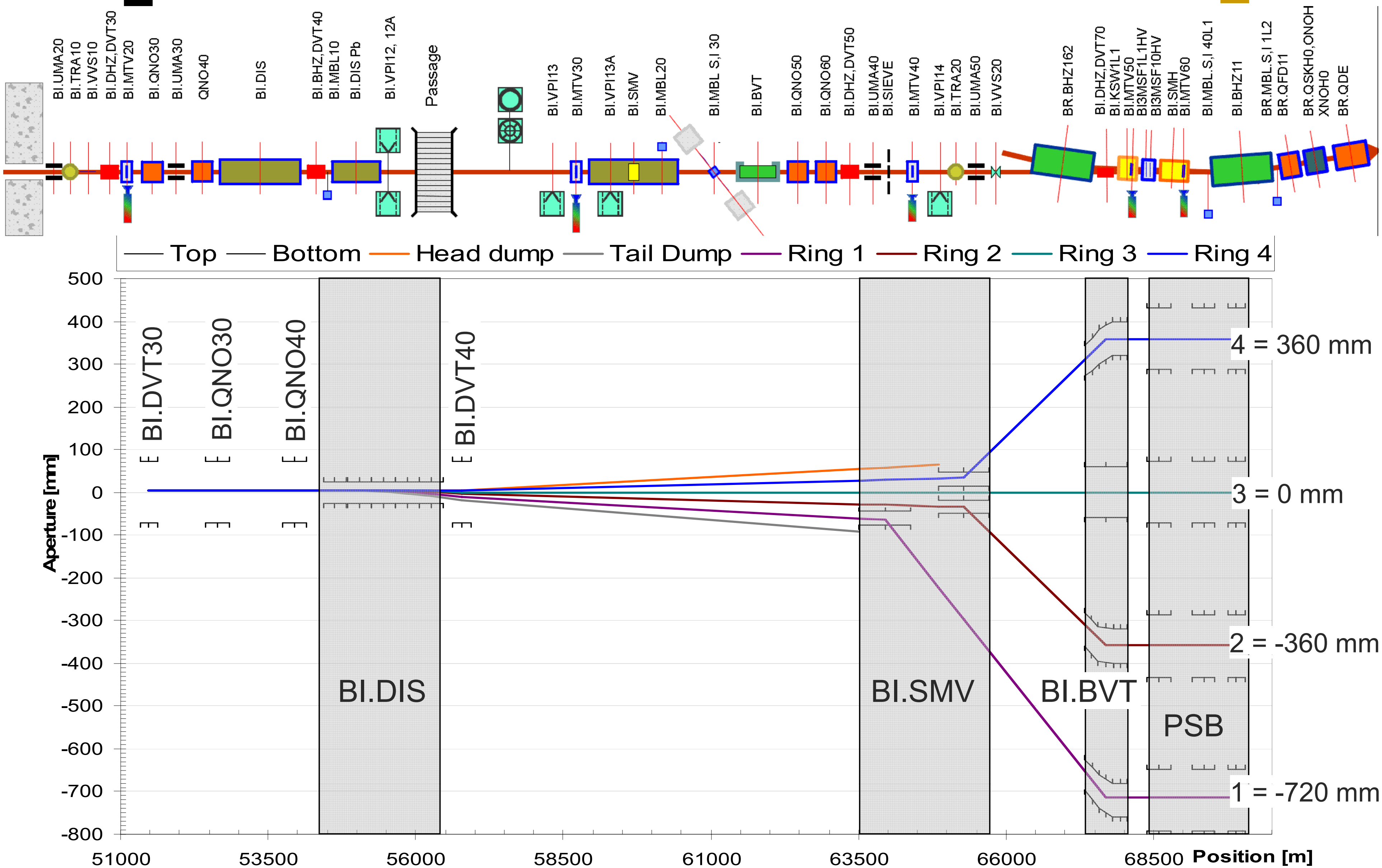
Proton Distributor BI.DIS
system of pulsed magnets, which kick slices of the beam to different vertical positions at the vertical septum BI.SMV

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

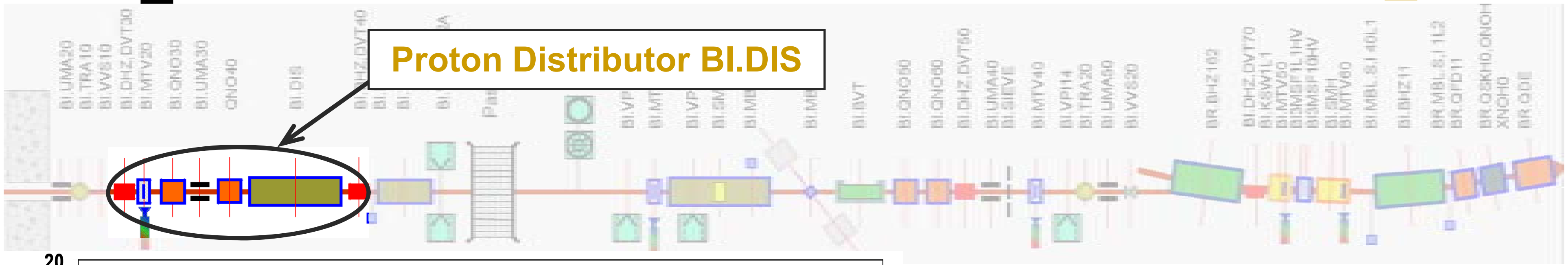


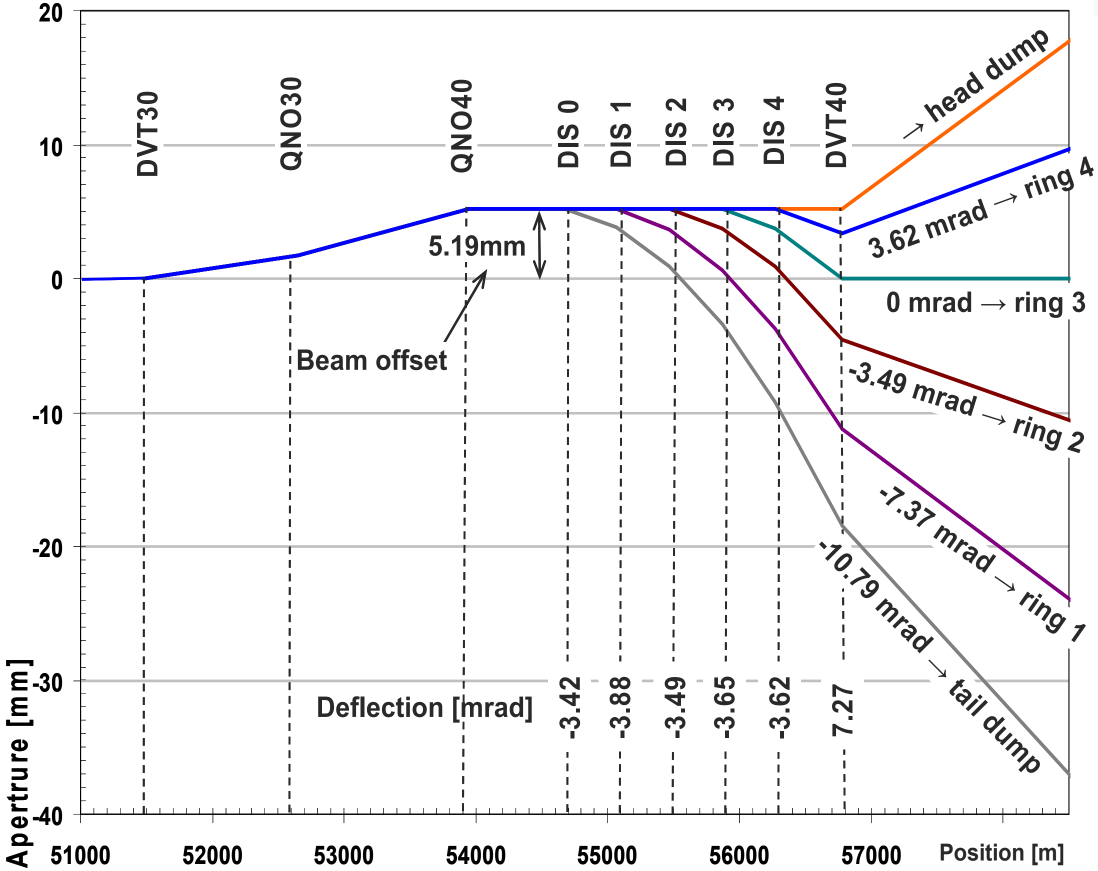
H^- Charge-Exchange Injection System
160 MeV H^- beam from LINAC4 is injected through a graphite stripping foil to convert ~98% of the beam to protons, using two independent closed orbit bump systems

Booster Injection Principle



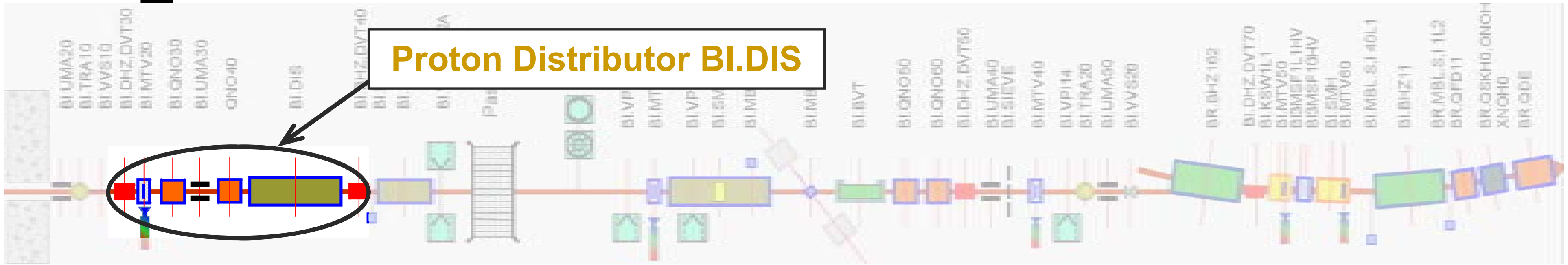
Booster Injection Principle



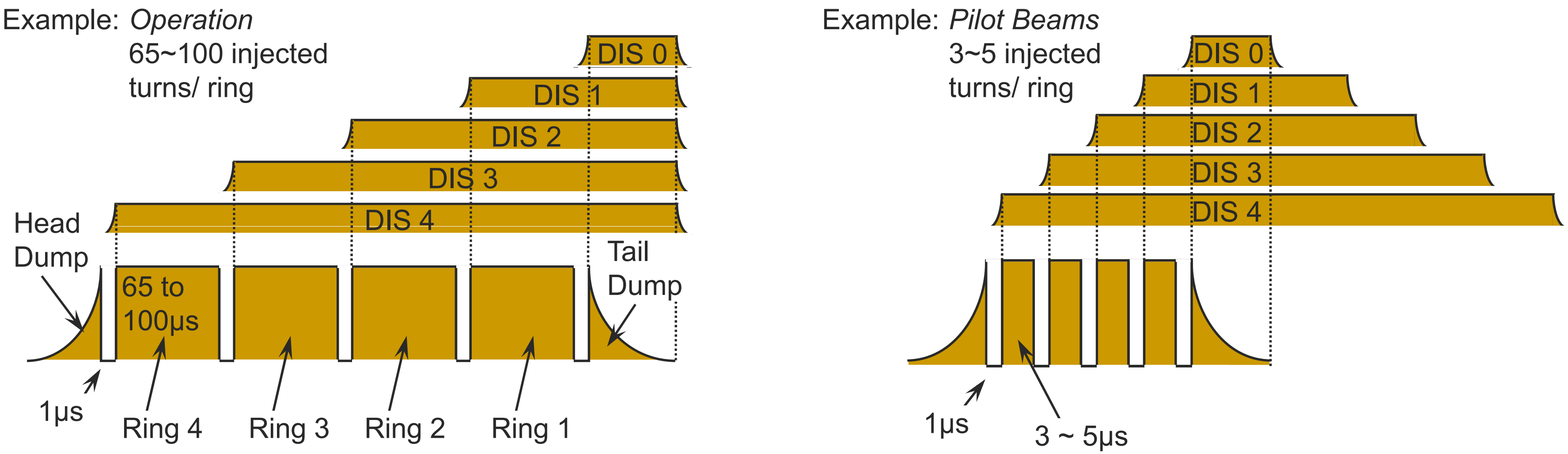


- *LINAC4 beam enters the BI.DIS with a ~5.2 mm vertical offset.*
- *The BI.DIS system, in combination with BI.DVT40, kicks slices of the beam into the different vertical septa BI.SMV.*
- *a ~3.5 mrad deflection producing a vertical beam separation of 35 mm at the the BI.SMV.*
- *In case of BI.DIS failure,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

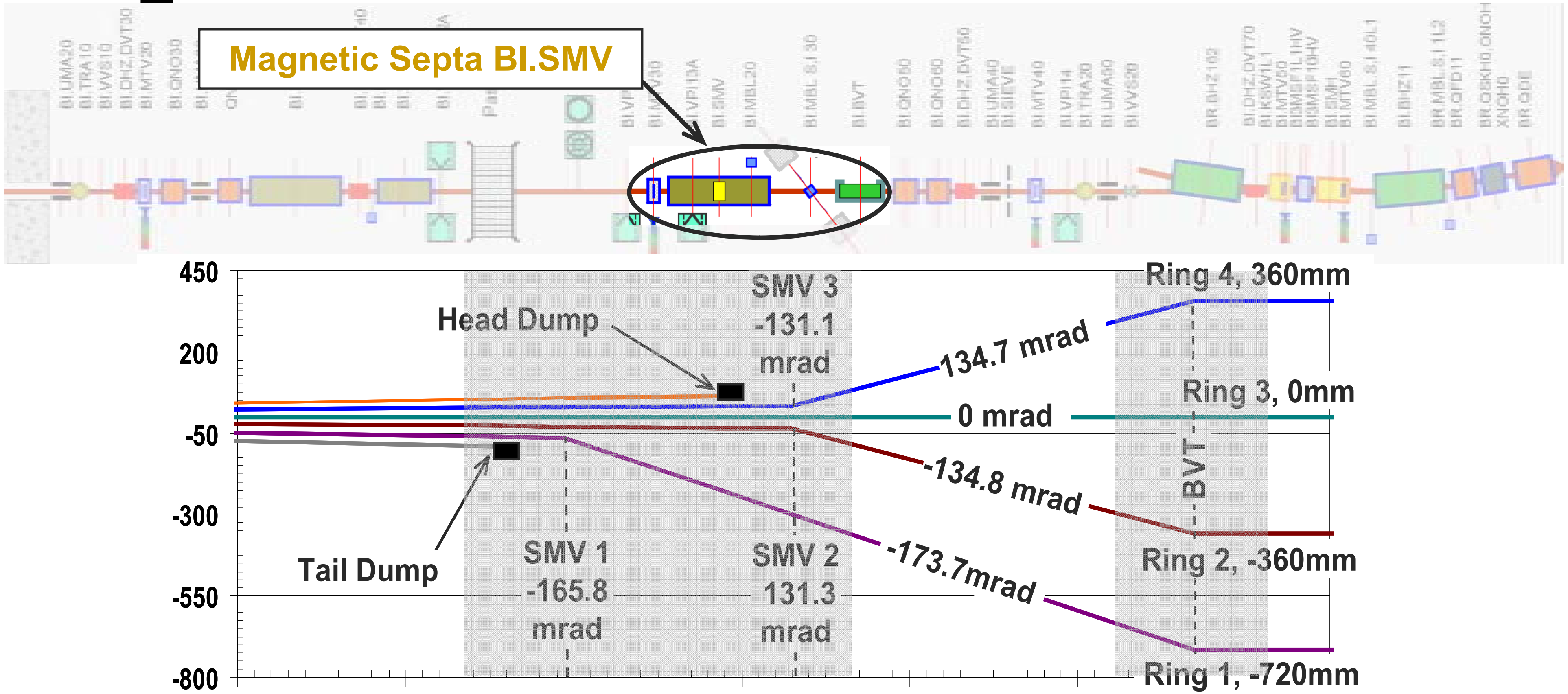
Booster Injection Principle — LINAC4 Pulse Structure



- *4 individual LINAC4 pulses, typically 65~100µs 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.*



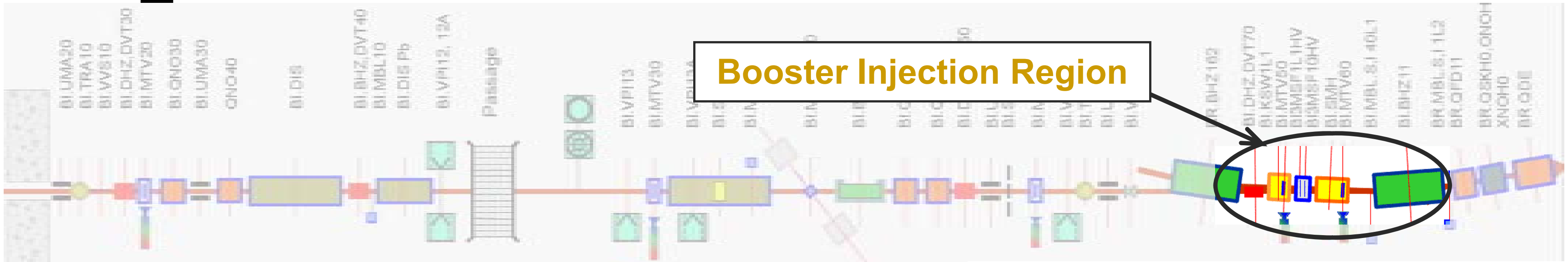
Booster Injection Principle

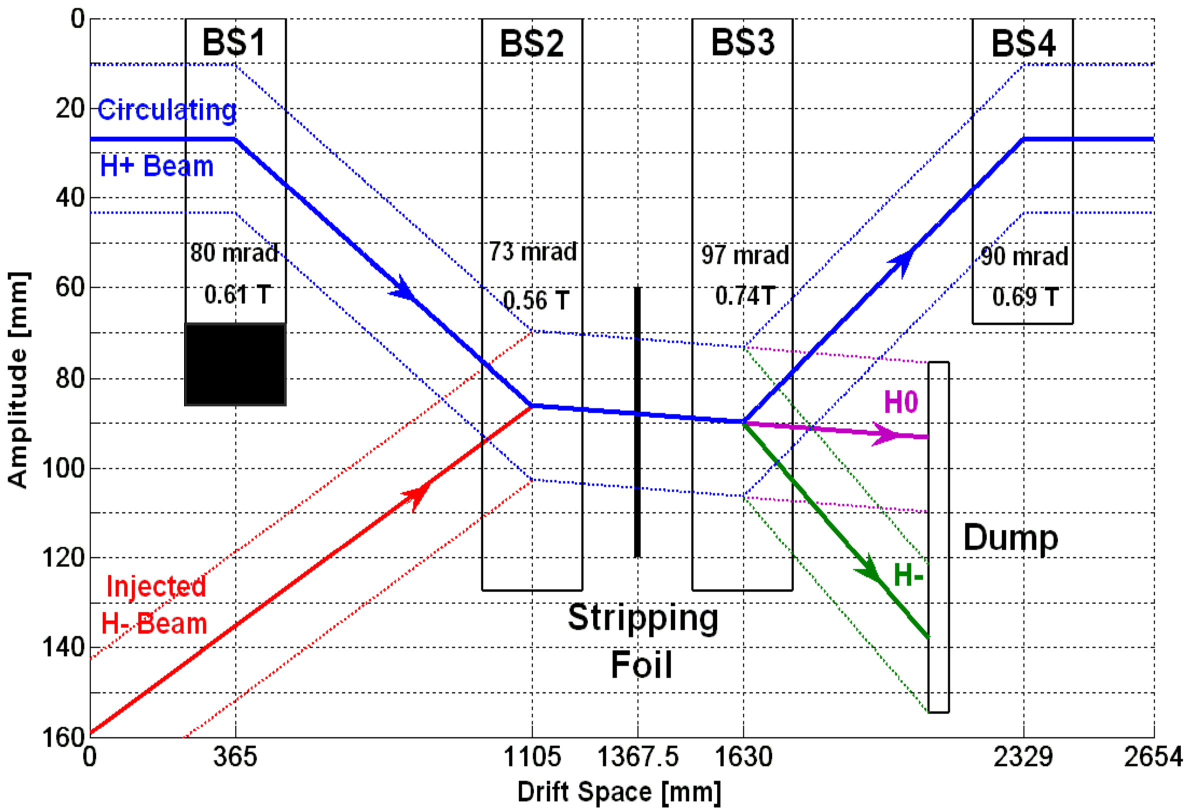


- *The rising edge of the LINAC4 pulse is deflected to a absorber block (head dump).*
- *BI.SMV septa deflect the beam vertically into apertures of 3 separate BI.BVT vertical dipole magnets to achieve the required PSB beam level separation of 360 mm between each ring.*
- *Beam designated for ring 3 will 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).*

H⁻ Injection System

Principle

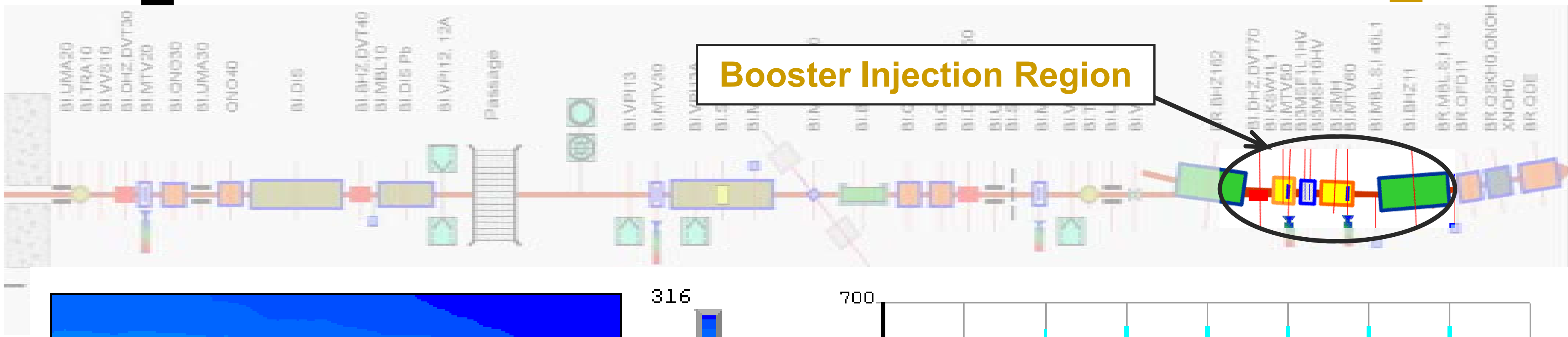


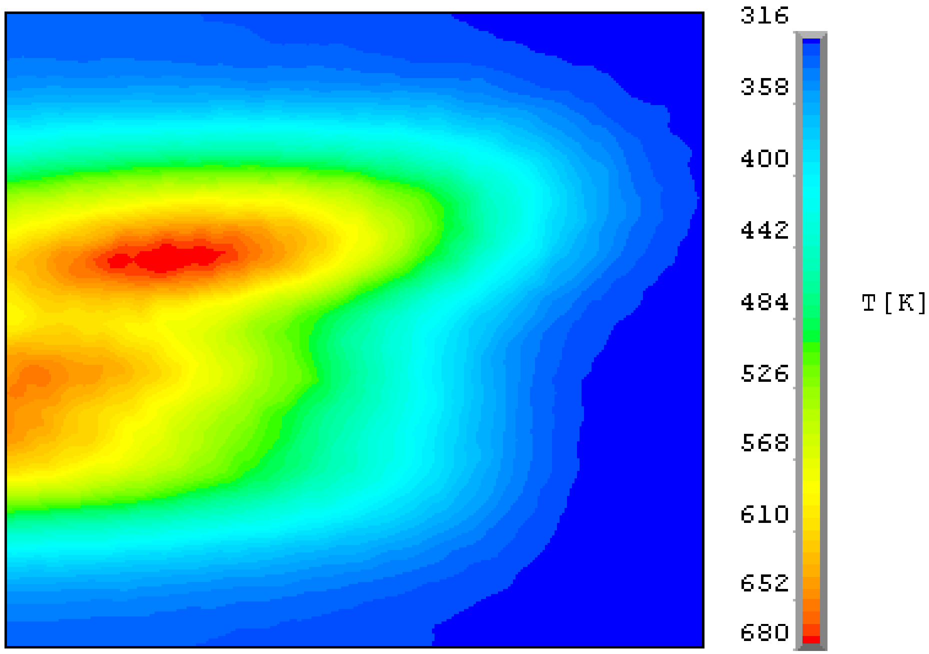


- *Two independent closed orbit bump systems:*
  - *<u>Injection Chicane</u>, 4 pulsed dipole magnets (BS), located in the injection region, giving 60 mm beam offset during the injection process.*
  - *<u>Painting Bump</u>, 4 horizontal kickers (KSW), located outside the injection region, giving 27 mm closed orbit bump with falling amplitude over the injection process for transverse phase space painting.*
- *BS1 must act as septum.*
- *BS4 should accommodate internal Dump.*
- *Stripping efficiency of ~98% expected.*

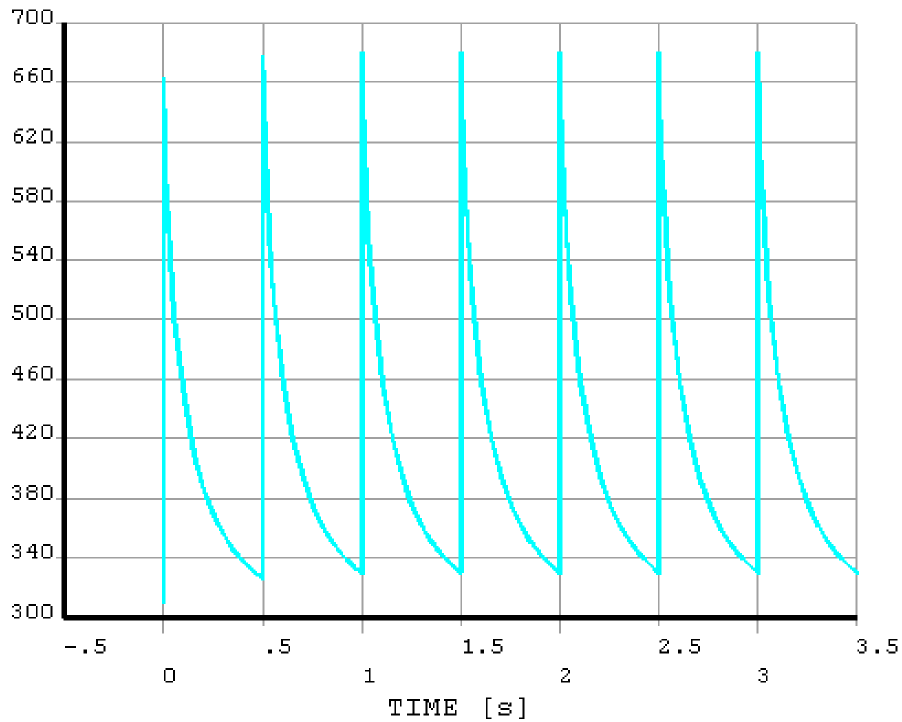
H⁻ Injection System

Foil Heating



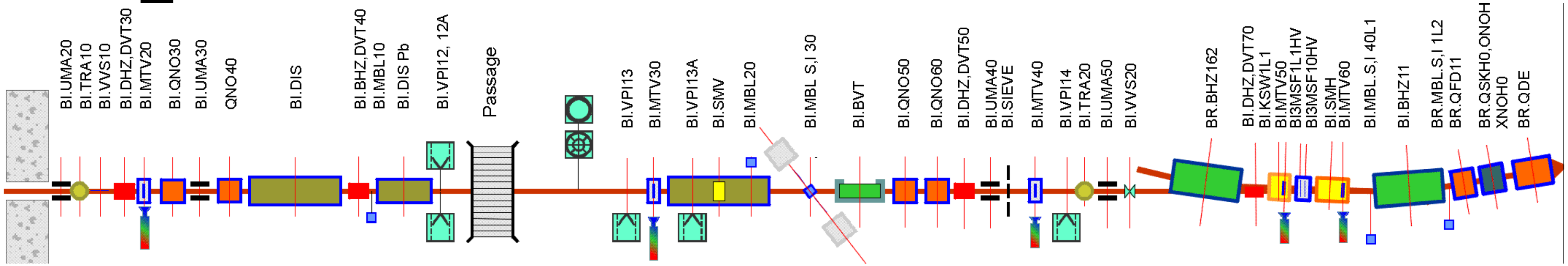


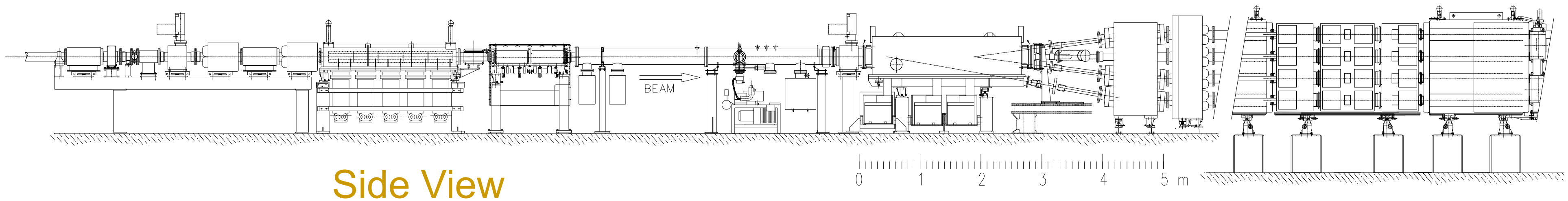
Temperature [K] of a 2 μm thick, 400 μg.cm-2 graphite foil at the end of the injection of 7 CNGS pulses.



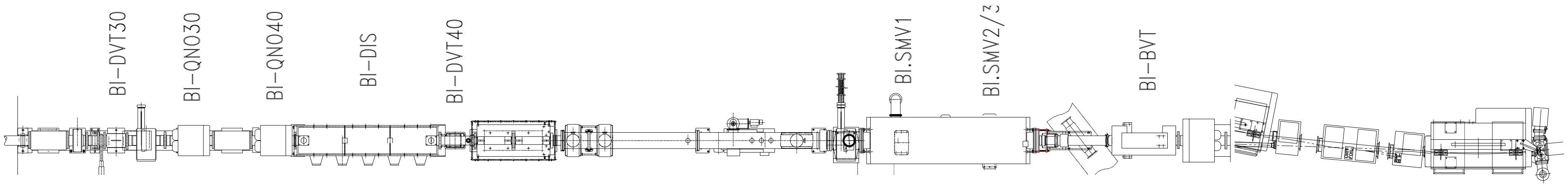
Peak foil temperature over 7 CNGS cycles.

Layout and Available Space



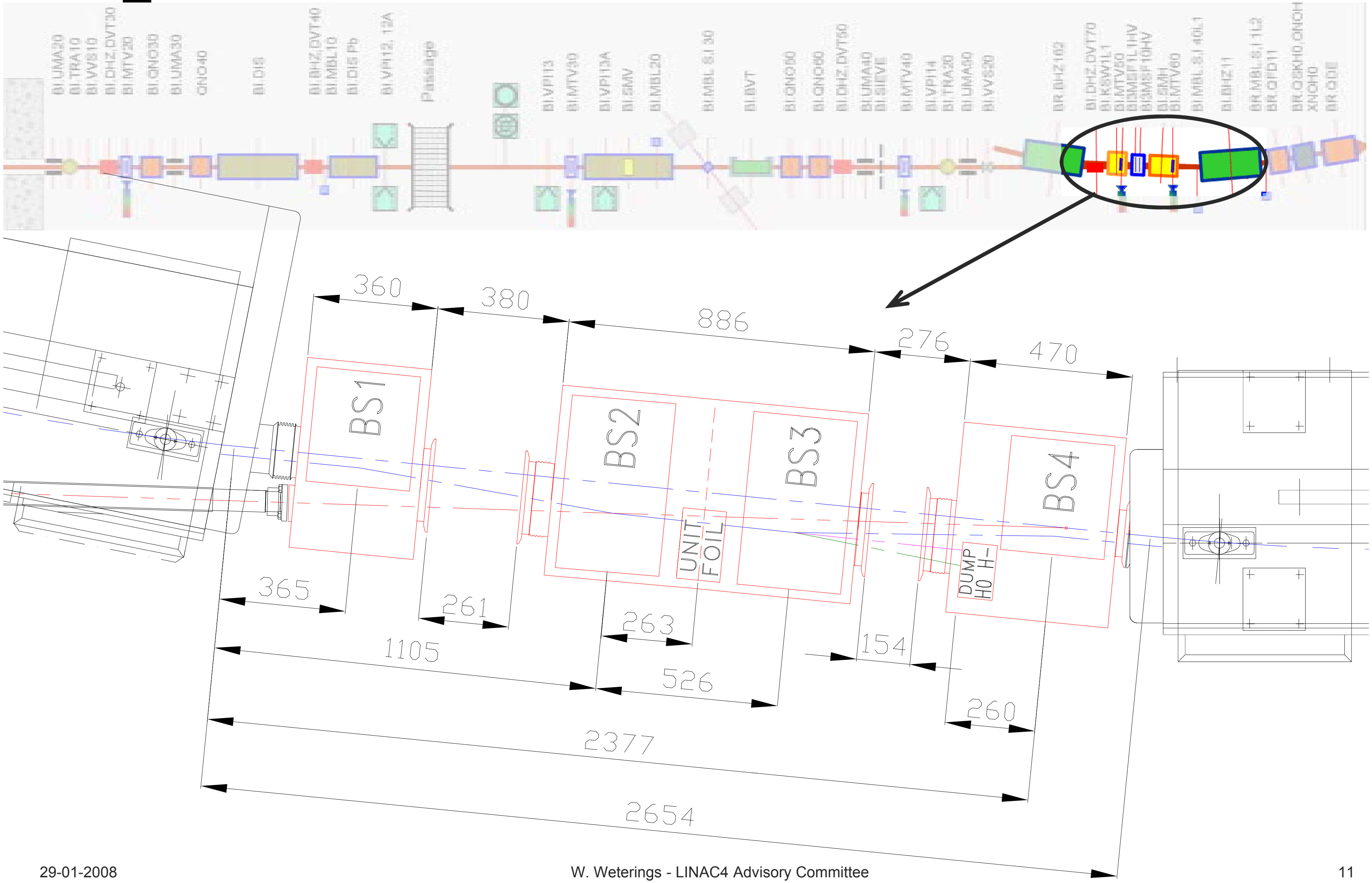


Side View

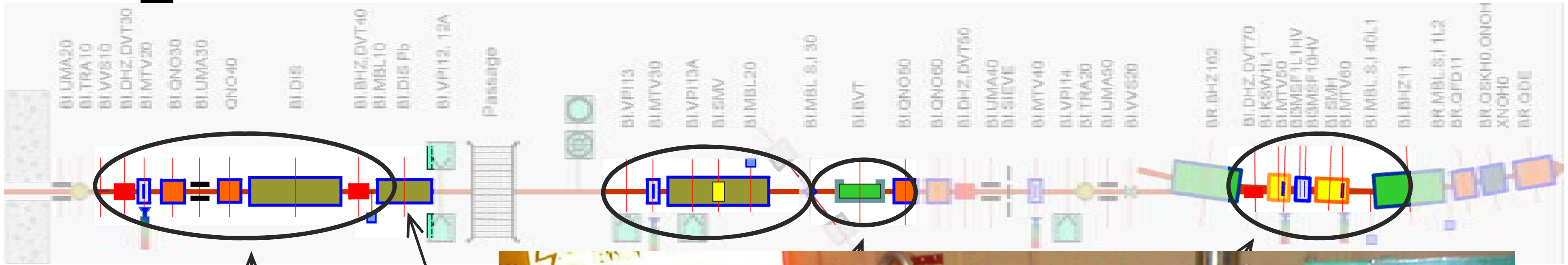


Top View

Layout and Available Space



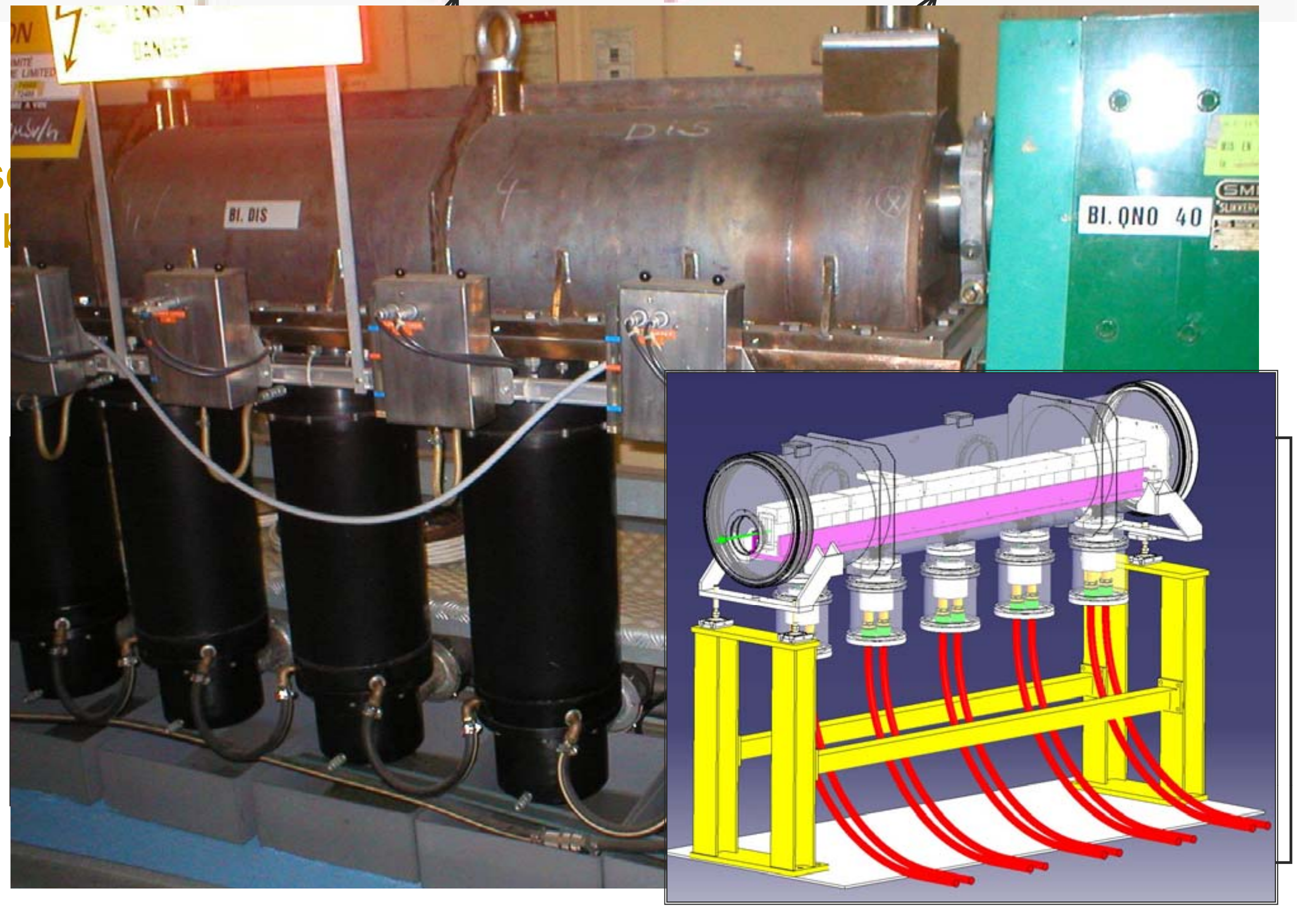
Required Modifications



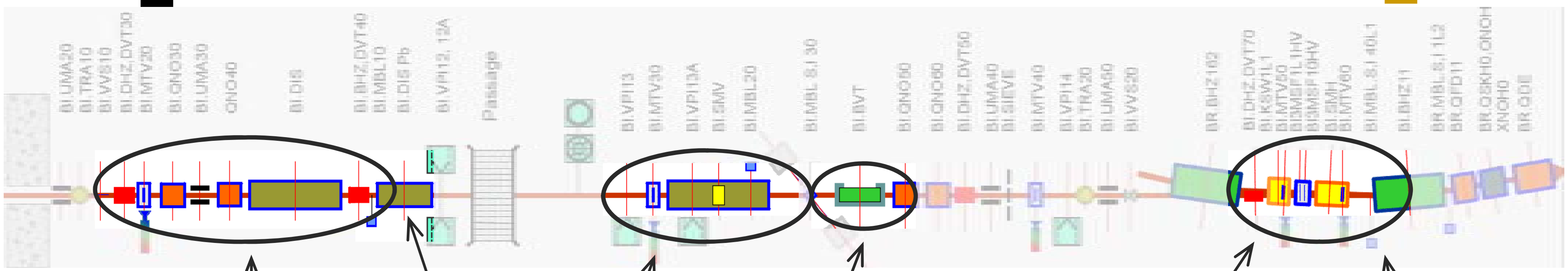
Remove obs
BI.DIS P

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.



Required Modifications



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 ~180 mrad @ 160 MeV. New pulse generator.

~0.36 Tm required from BI.BVT for ~187 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.

Main Design Parameters

		BI.DIS	BI.SMV	BS1,4	BS2,3
Deflection angle	mrad	4.3	170	92	100
Integrated field	mTm	8.2	324	175	190
Gap field	mT	23.1	337	700	760
Beam acceptance	mm	98	32	62	62
Gap width	mm	50	70	130	200
Magnetic length	Mm	354	960	250	250
Peak current	kA	0.95	18.3	2.56	2.78
Magnet inductance	µH	0.9	1.3	75	116
Magnet resistance	mΩ	0.03	0.1		
Number of turns		1	1	10	10
Repetition rate	Hz	1.11	1.11	1.11	1.11
Rise / Fall time	µs	1		40	40
Flat Top duration	µs	420	100	100	100

Present Status

- *BI.DIS* - *Design of new vacuum vessel well advanced.*
  - *Existing magnet tested for 160 MeV operation.*
  - *Specification for ferrite cores in preparation.*
  - *Coil design under study.*
  - *Challenge: Operation at 30 kV.*
- *BI.SMV* - *Magnet parameters have been defined.*
  - *Design & prototyping planned to start mid 2008.*
  - *Challenge: Build curved, high induction, septum magnet to operate under vacuum.*
- *KSW* - *Studies of moving 1L1 to period 16 ongoing.*
  - *If moved, build outside vacuum magnets.*
  - *Challenge: Beam optics compatibility.*

Present Status

- *BS* - *Basic prototype has been tested to validate OPERA™ simulations.*
  - *3D finite element transient field analysis ongoing.*
  - *Aperture and parameter optimization studies.*
  - *Challenge: Build cost-effective fast pulsed bumper system.*
- *Foil Unit* - *Nuclear foil physics effects are being studied.*
  - *Challenge: Foil changing unit in limited space.*
- *H^o/H^- Dump & Head/Tail Dumps*
  - *Thermo-mechanical studies being prepared.*
  - *Challenge: Robust dumps in limited space.*

Overall Challenge:

Injection system for 4 Superimposed PSB rings

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 $\int B \cdot dl$ 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.*