Dummy septum: beam dynamics and shadowing studies

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Outline

Design strategy for the dummy septum

Efficiency of the dummy septum

Beam dynamics constraints on the blade positioning

Shadowing efficiency studies

Conclusions

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Design strategy for the dummy septum 15

Need to reduce the MTE losses around SMH16 !

Shadowing of the blade of SMH16

- **Intercept particles that without the dummy septum would be lost on SMH16**
- Losses induced on SMH16 should be reduced by a large factor (4 to 10)

What it should not do

- Intercept particles that without the dummy septum would not be lost in SMH16 → should not increase the overall losses
- Perturb mechanically the other beams during extraction. TOF shown to be the most critical
- Contribute to a too large impedance

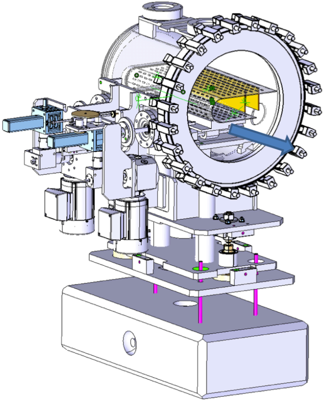

Figure 1: Dummy septum tank *.

M. Hourican, 2012.

Design strategy for the dummy septum scheme

Extraction scheme strategy

- Push the MTE slow closed bump to have the outer island close to the blade (and maximize the blade radial position)
- Outer island jumps toward the exterior side during the transient induced by the fast closed bump. Core jumps during the transient of the fast kick
- Slow closed bump of the other beams reduced (if needed) not to touch the blade during their slow bump and during their fast extraction kick → other beams stay on the inside of the dummy septum blade*

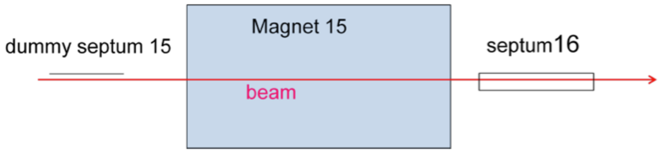

Figure 2: It started with a simple idea !

** Except for the deflected CT slice*

Design strategy for the dummy septum scheme

The shadowing of SMH16 by the blade is constrained by

- the optics of MU15 (transfer line propagation from SS15 to SS16) $\rightarrow$ fixed
- the blade's position $\rightarrow$ constrained by the other beams
- the orbit angle (X') of the beam interacting with the blade $\rightarrow$ can be adjusted (iterative process)

$$\Downarrow$$

(1) — Other beams suggest possible blade position $\rightarrow$ blade as low as possible compatible with that constraint: small range for X

(2) — Set correct slow and fast bumps settings for MTE $\rightarrow$ starting point for a range of X' and for the time dependance

(3) — Evaluate the shadowing (for slightly different positions of the blade) (can we improve it changing SMH16 position ?)

(4) — Iterate to maximize the efficiency (how do we define the efficiency ?)

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Efficiency of the dummy septum

We need numerical parameters to assess the performance of a given geometry / blade positioning

How can we quantify the efficiency ?

- Ratio of the total losses (with DS15) with the losses without DS15: $L_r = \frac{L_{DS}}{L_{/}}$, or total reduction factor: $R_{\text{tot}} = \frac{L_{/}}{L_{DS}}$
- Losses with the DS15 in place: L^{15}_{DS} and L^{16}_{DS}
- Reduction factor for the losses at SMH16 with and without DS15: $R_{16} = \frac{L^{16}_{/}}{L^{16}_{DS}}$
- Global parameter to be maximized: $\epsilon = \frac{R_{16}}{L_r} = R_{16} \times R_{\text{tot}}$

$\Rightarrow$ these are ways of “counting the protons”, but we are also interested in the global dose rate map ...

Efficiency of the dummy septum

Dose rate maps

- Reference map established for a realistic beam distribution in the absence of the dummy septum, valid around the extraction region
- Serve as the normalization for the maps obtained for different geometries of the dummy septum

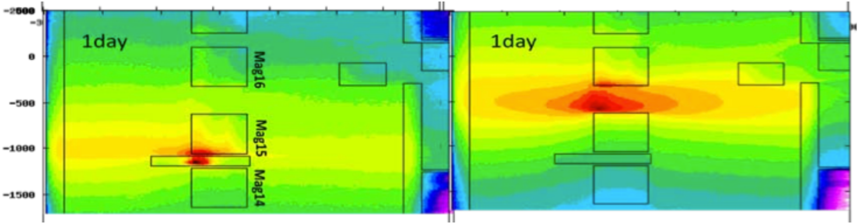

Figure 3: Stray radiation maps obtained for a pencil beam lost on the dummy septum 15 (left) or on the magnetic septum 16 (right)*

S. Damjanovic et al., 2011

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MTE beam envelopes in SS15 and SS16

Beam dynamics studies

- Slow and fast bump found for the MTE beam → compatible with the positioning of the blade in SS15. Negative angle in SMH16 compatible with the strength of the septum
- Modified slow bump and kick for the TOF beam → defines the minimal amplitude to position the blade (to be further tested experimentally)
- Other beams less problematic. Deflected CT slice "naturally" on the other side of the blade

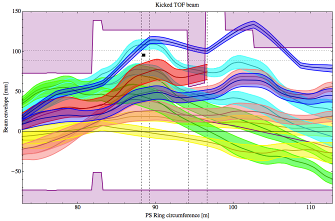

Figure 4: Beam envelopes around SS15/16

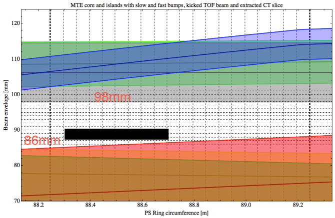

Figure 5: MTE fast bump and kicked TOF

Constraints for the blade positioning

- Free space available around $X = 90$ mm $\rightarrow$ for beam with small angle this is at the limit to obtain shadowing
- Beta function in SS15 is 2 times the one in SS16 $\rightarrow$ we choose a thicker blade: $\sqrt{2} \times 3$mm
- Angle of the fast bump in SS15 spans a large range as a function of time (more complicated optimization – core angle is more stable)
- The TOF beam has a positive angle, place the blade as much as possible at the beginning of the straight section (compatible with current shielding design)

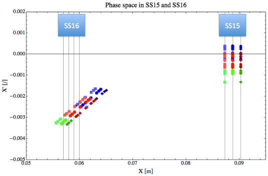

Figure 6: Angular spread and shadowing

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Fluka/PTC simulations

Simulation strategy

- Generate a realistic beam distribution at the start of SS15
- Transport it with Fluka through SS15 $\rightarrow$ realistic interaction with the dummy septum blade
- Evaluate the losses in SS15 $\rightarrow$ dose rate Map_{15}
- Track the remaining particles through MU15 $\rightarrow$ correct propagation in the magnet (Fluka geometry does not contain the curvature)
- Transport the distribution in SS16 $\rightarrow$ realistic effect of the complex interaction with the blades of SMH16
- Evaluate the losses in SS16 $\rightarrow$ dose rate Map_{16}
- The circulating beam at the end of SS16 can be tracked in the rest of the machine to check for hot spots along the ring
- Sum the dose rate maps $\rightarrow$ dose rate $\text{Map}_{\text{total}} = \text{Map}_{15} + \text{Map}_{16}$

Nomenclature: start of SS(N) means end of the coils of MU(N-1)

Realistic beam distribution at the start of SS15

- Consider the time dependance of the fixed point coordinates from the beginning of the pulse (*i.e.* slow bump) to its maximum (*i.e.* static conditions of the fast bump)
- From optical properties of the beamlets, generate beam distributions (*) at different timesteps (sampling)
- Aggregate these distributions into a single time independent distribution (long pause picture of the beam during the fast bump)
- To be done for the islands and for the core

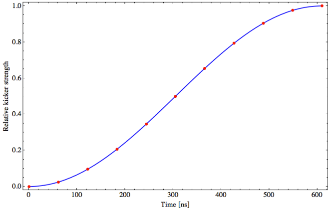

Figure 7: Time evolution of the kickers (KFA13,21) strength during the pulse

Gaussian beam distribution, optical parameters from the model, emittance matching measurements

Realistic beam distribution at the start of SS15

Normalization of the distribution

The distribution represent a fraction of the beam in the machine corresponding to the rise time of the kickers.

$$w = \frac{1}{N}\frac{1}{5}\frac{T_{\text{rise}}}{T_{\text{rev}}},\ N = \text{\# of particles} \quad (1)$$

- Island beam distribution represents $w_I \times N =$5.8% of the circulating beam
- Core beam distribution represents $w_C \times N =$1.1% of the circulating beam

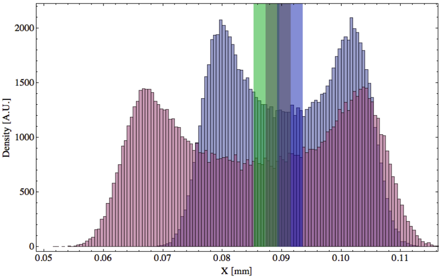

Figure 8: Aggregated distribution at the start of SS15 for the core (red) and for the outer island (blue)

Interactions with the blade

- A fraction of the beam interacts with the blade, we filter the secondaries and count the protons entering in the vacuum chamber of MU15
- Clear effect of the mixing between position and angle

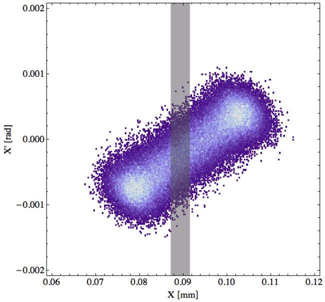

Figure 9: Start of SS15 and position of the blade

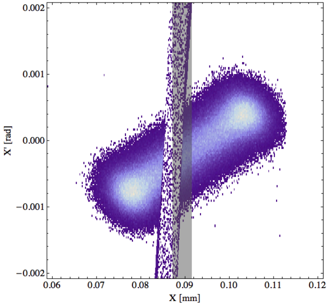

Figure 10: End of SS15, hole in the distribution

Losses in SS15 and MU15 with dummy septum: L_{DS}^{15}

Blade	Isl. SS15	Core SS15	Total SS15	Total MU15	Total
(1) 87.3 - 91.5 mm	0.46	0.060	0.52	0.11	0.63
(2) 89.3 - 93.5 mm	0.46	0.062	0.52	0.066	0.59
(3) 85.3 - 89.5 mm	0.48	0.059	0.54	0.078	0.62
(4) 84.8 - 90.0 mm	0.61	0.074	0.68	0.125	0.81
(5) 85.3 - 89.5 mm *	0.55	0.069	0.62	0.099	0.72

* Blade rotated with an angle of 3 mrad toward the exterior side of the machine

Table 1: Fraction of the beam lost in SS15 and MU15

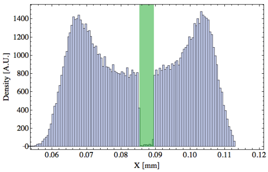

Figure 11: Hole created by the blade (3)

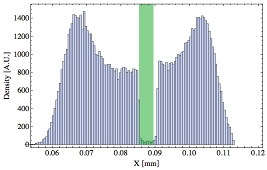

Figure 12: Hole created by the blade (5)

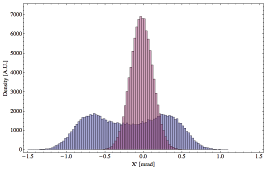

Figure 13: Initial angular spread

Interactions in SS16

Beam is tracked through MU15 with PTC, we analyze the distribution at the begining of SS16

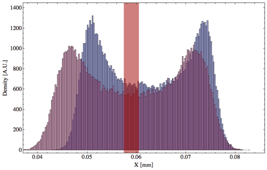

Figure 14: No dummy septum

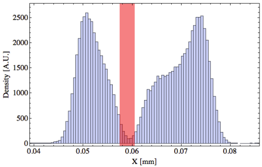

Figure 16: With dummy septum

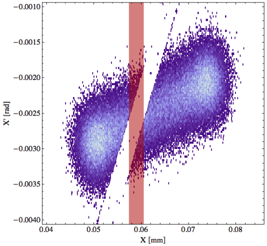

Figure 15: Island distribution interacting with SMH16

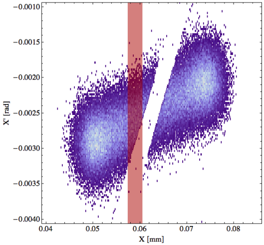

Figure 17: Island distribution interacting with SMH16

Losses in SS16: L_{DS}^{16}

Blade ↓ - SMH16 →	55.5mm	57.5mm	57.5mm (isl. only)
(1) 87.3 - 91.5 mm	0.47	0.27	0.20
(2) 89.3 - 93.5 mm	0.56	0.45	0.38
(3) 85.3 - 89.5 mm	0.29	0.14	0.096
(4) 84.8 - 90.0 mm	0.20	0.068	0.057
(5) 85.3 - 89.5 mm *	0.28	0.077	0.064
(/) No blade	0.55	0.52	0.44

* Blade rotated with an angle of 3 mrad toward the exterior side of the machine

Table 2: Fraction of the beam lost by interaction with SMH16

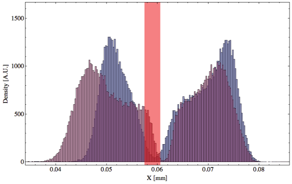

Figure 18: Distribution at SMH16

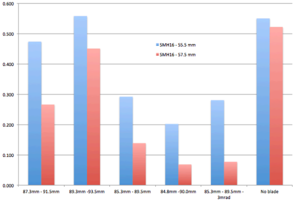

Figure 19: Losses SMH16

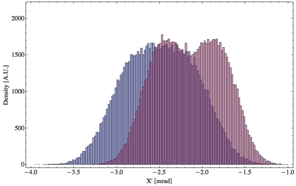

Figure 20: Angular spread in SS16

Real Fluka tracking in SS16

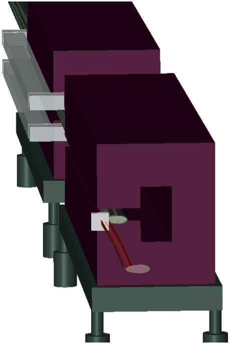

Figure 21: Bent trajectory in SMH16

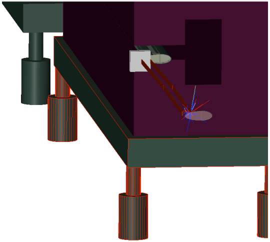

Figure 22: Interaction with SMH16

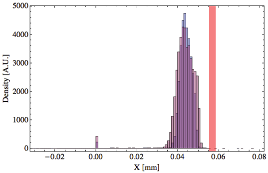

Figure 23: Real Fluka tracking in SS16 – Effect of the negative value of the orbit angle in SS16

- Now we considered only the losses *via* a geometrical “black hole”
- Interactions with the blade are more complex
- Magnetic field of SMH16 added: 0.6 T, nominal value at 14 GeV/c
- Geometry of the two blades checked with drawings

Efficiency parameters

Summary with global parameters

Blade	ϵ	R_{tot}	R_{16}	L_{DS}^{15} [%]	L_{DS}^{16} [%]
(3)	2.59	0.69	3.76	0.62	0.14
(4) Thick	4.58	0.60	7.63	0.81	0.068
(5) Angle *	4.46	0.66	6.76	0.72	0.077

Table 3: Efficiency parameters for SMH16 at 57.5mm

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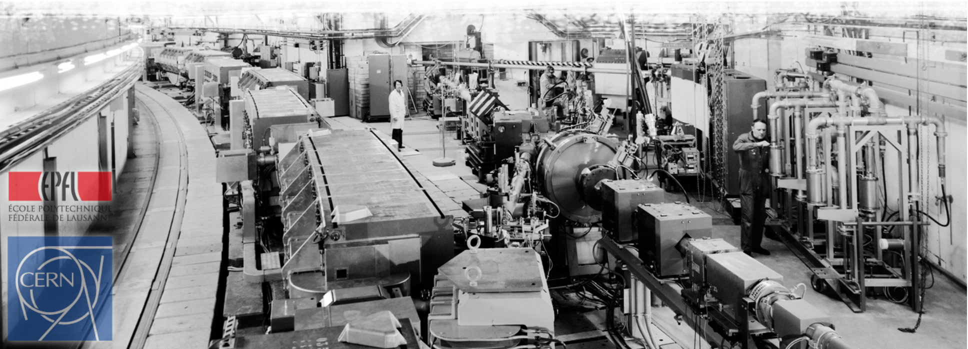
Conclusions [preliminary]

- Coupled Fluka/PTC simulations are working
- A first iteration has been completed $\rightarrow$ we now need to close the loop and iterate
- Preliminary results have been obtained, mainly on the reduction factor we can expect for the losses on SMH16
- ...

Thanks !

Questions ?



Backup

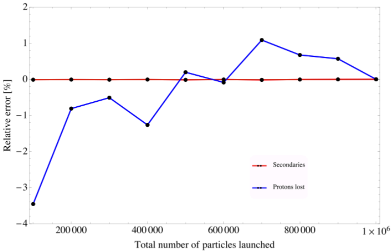


Figure 24