Dispersion Suppressor Protection

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Acknowledgments to:
I. Besana, R. Bruce, F. Cerutti, M. Fiascaris, A. Langner, A. Lechner, J. Molson, H. Rafique, D. Schulte
Why is Protection necessary?

M. Fiascaris, Rome 2016

Target: $3 \times 10^{-7}$

from tentative scaling of LHC loss rate about $O(70)$ too high

D. Schulte, Rome 2016
Why is Protection necessary?

First Sixtrack simulations from last year showed high losses in the Dispersion Suppressors after the Betatron cleaning.

Target 3 x 10^{-7}

from tentative scaling of LHC loss rate about O(70) too high

M. Fiascaris, Rome 2016

D. Schulte, Rome 2016
Proposal at FCC-Week 2016: Dispersion Suppressor collimators
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A. Langner

Betatron Collimation Insertion (2.8km)

Dispersion suppressor region

Primary collimators
Secondary collimators
Shower absorbers

7.5cm
Dipoles
Proposal at FCC-Week 2016: Dispersion Suppressor collimators

- Efficiency of collimation system
- Impact of showers generated in the DS collimators
Energy collimation has been included

Beta function and Dispersion in the DS region have been optimized to improve efficiency of collimators.
2.44 \cdot 10^9 \text{ Particles over 250 turns}

Lossmaps with Merlin
Lossmaps with Merlin, DS included

2.49 \cdot 10^9 \text{ Particles over 250 turns}

3 \cdot 10^{-7}
Similar efficiency in cell 8 and cell 10, but impact parameters are more challenging in cell 8.
TCLD Cell 8

Sum of relative losses on TCLD: \(1.083 \cdot 10^{-4}\)

12 min beam lifetime \(\approx 1.3\text{kW total load}\)
• Input generation
• Geometry description
• Scoring

Visualization done with SimpleGeo (C. Theis, CERN)
FLUKA simulations

- Input distribution is generated from Merlin tracking
  - Every turn the whole bunch is recorded before the collimator.
  - Particles which hit the collimator are selected.
  - This distribution is loaded into FLUKA and particles are randomly selected from it.

- Energy deposition is scored in a meshgrid of bins.
  - Scoring in the coils with 0.5 cm radial, 2° angular and 5 - 10 cm longitudinal binning.
1 Meter Collimator

Material: Inermet 180
Halfgap: $35.14 \sigma / 1.3 \text{ mm}$
Energy cut: $\frac{\Delta p}{p} = 6.76 \cdot 10^{-3}$
Geometry for FLUKA simulations

1 Meter collimator
+ 50 cm Mask

Material: Inermet 180

Visualization done with SimpleGeo (C. Theis, CERN)
Geometry for FLUKA simulations

1 Meter collimator
+ 1 Meter collimator
+ 50 cm Mask

Material: Inermet 180
Halfgap: 79.22 $\sigma$ / 2.6 mm

Visualization done with SimpleGeo (C. Theis, CERN)
Simplified MQ coil model (based on P. Vedrine, Rome 2016)

Simplified MB coil model (based on V. Marinozzi, Rome 2016)

Confirmed with D. Schörling

Coil material:

50% $Nb_3Sn$, 50% $Cu$
Energy Deposition - Quadrupole

Maximum Energy deposition in the Quadrupole coils (MQDA.8RJ)

5-10 mW/cm$^3$

magnet limits
E. Todesco
Energy Deposition - Dipole

Maximum Energy deposition in the Dipole coils (MB.A9RJ)

- 1m
- 1m + Mask
- 1m + 1m + Mask

5-10 mW/cm³
magnet limits
E. Todesco
Merlin and Sixtrack with FLUKA coupling show good agreement in the DS region (difference $O(5 - 10\%)$).

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• Merlin and Sixtrack with FLUKA coupling show good agreement in the DS region (difference \(O(5 - 10\%))\).


• Comparisons of simulations and measurements at the LHC showed a factor 2-3 discrepancy.


• No imperfections or magnet errors have been taken into account.
Energy Deposition

Maximum Energy deposition in the Quadrupole coils (MQDA.8RJ)

- 5-10 mW/cm³ magnet limits
- E. Todesco

Factor 4
(discrepancy + uncertainty)
Maximum Energy deposition in the Dipole coils (MB.A9RJ)

Factor 4
(discrepancy + uncertainty)

5-10 mW/cm$^3$
magnet limits
E. Todesco
Conclusion

• The critical problem of cold losses in the Dispersion Suppressors has been addressed.
  • Energy deposition studies have been carried out for the most critical case in cell 8 after the Betatron cleaning insertion.

• Inclusion of energy collimation and optimizations in optics gave a factor $\sim 2-3$ reduction of cold losses.

• Placement of collimators and masks in cell 8 and cell 10 reduces the direct cold losses below the tentative goal of $3 \cdot 10^{-7}$

• Additional elements are needed to protect the magnets from the particle showers

• With additional 1 meter collimators an important safety margin could be obtained and also gives possibilities for future upgrades.

• The same protection system proves to be effective to protect the Dispersion Suppressors around the experiments from continuous collision debris losses.
• Optimization of DS collimator gaps around the ring
  • Especially concerning changes of the energy collimation hierarchy

• Stress and heat-transport studies for the DS collimators

• Verification with energy deposition simulations that cell 10 is less problematic.

• Tracking studies for injection, ramp and squeeze.
  • DS collimator gaps for the respective operation modes.
  • Energy deposition studies, if impact parameter differ significantly from top energy case.

• Further studies to validate if the current DS collimation system is sufficient for Ion operation as well.
Energy Deposition around IP

Energy deposition in the Dispersion Suppressors after IPA from collision debris.

Maximum Energy deposition in the Quadrupole coils (MQDA.8RA)

- Input distribution from H. Rafique. (H. Rafique, A. Krainer, IPAC17)
- 5-10 mW/cm$^3$
- 1m Baseline
- 1m Ultimate
- 1m + Mask Baseline
- 1m + Mask Ultimate

5-10 mW/cm$^3$ magnet limits

E. Todesco