Collimation Review 2011
Summary Input

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for the collimation team

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LHC Collimation Project Review

Required Cleaning Efficiency

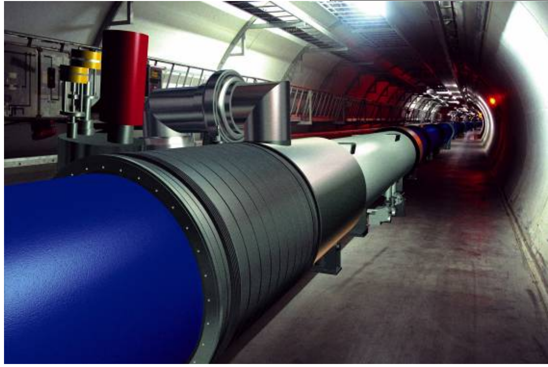

Illustration of LHC dipole in tunnel

Allowed intensity

Quench threshold (7.6 ×10^6 p/m/s @ 7 TeV)

$$N_p^{\max} \approx \tau \cdot R_q \cdot F_{BLM} \cdot L_{dil} / \eta_c$$

Beam lifetime (e.g. 0.2 h minimum)

BLM threshold (e.g. 30%)

Loss length

Cleaning inefficiency = $\dfrac{\text{Number of escaping p } (>10\sigma)}{\text{Number of impacting p } (6\sigma)}$

Collimation performance can limit the intensity and therefore LHC luminosity.

Proton Performance Reach from MD: 3.5 TeV

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Loss rate at quench / BLM limit

$$N_p^{\max} \geq \tau \cdot R_q \cdot F_{BLM} \cdot L_{dil} / \eta_c$$

$$\approx \tau \cdot R_{loss}^{DS} / \eta_c = \tau \cdot R_{loss}^{prim} \cdot \eta_c / \eta_c = \tau \cdot R_{loss}^{prim}$$

Measured MD1:

$$N_p^{\max} \geq \tau \cdot R_{loss}^{prim} = 3.2 \times 10^{15}\, p$$

3600 s **9e11 p/s**

Extrapolated with MD2: Factor 3.3 better inefficiency from second MD

$$N_p^{\max} \geq 3.3 \cdot \tau \cdot R_{loss}^{prim} = 1.1 \times 10^{16}\, p$$

CERN-ATS-Note-2011-042 MD (LHC)

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Collimator losses in the DS of IR7 and quench test at 3.5 TeV

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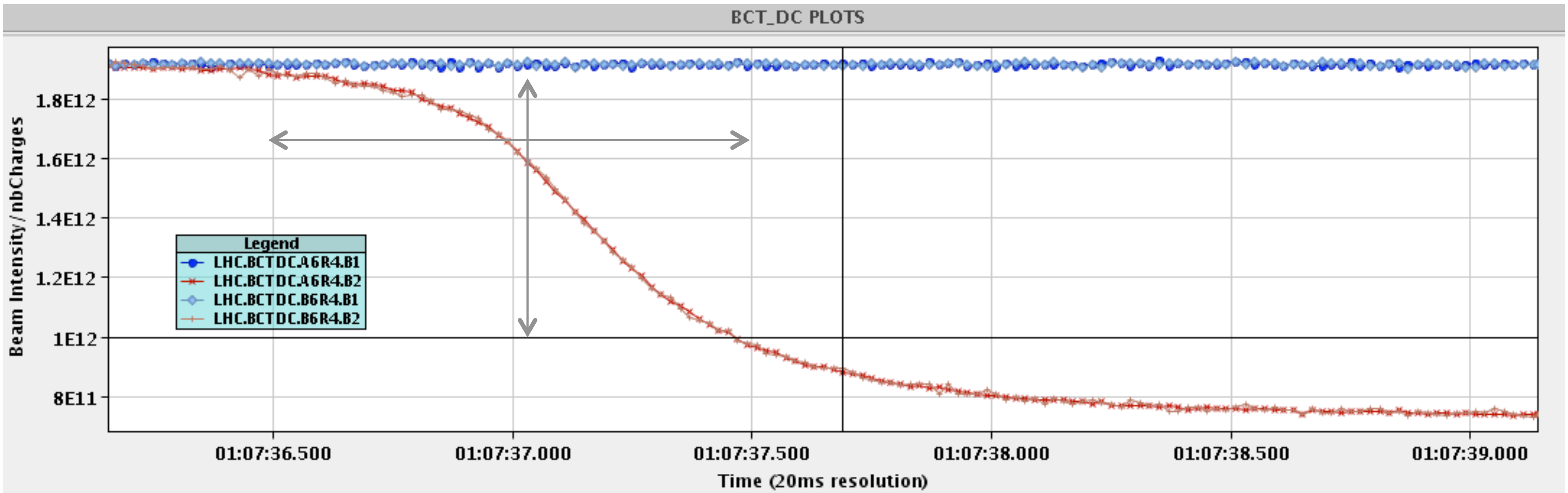
Keywords: Collimation, beam losses, quench, dispersion suppressor

16 bunches, 3.5 TeV

Provoked beam loss: beam blow up on 1/3 resonance



Loss rate:

9e11 p/s @ 3.5 TeV → 505 kW

Proton Performance Reach from MD: 3.5 TeV

at quench / BLM limit

$$N_p^{\max} \geq \tau \cdot R \cdot F$$

$$\approx \tau \cdot R \quad {}_{loss}$$

Estimate independent of dilution length, quench limit and BLM response functions!

Measured MD1:

$$N_p^{\max} \geq \tau \cdot R_{loss}^{prim} = 3.2 \times 10^{15}\, p$$

3600 s **9e11 p/s**

Extrapolated with MD2: Factor 3.3 better inefficiency from second MD

$$N_p^{\max} \geq 3.3 \cdot \tau \cdot R_{loss}^{prim} = 1.1 \times 10^{16}\, p$$

Proton Performance Reach from MD: 7 TeV

Measured MD1 put to 7 TeV:

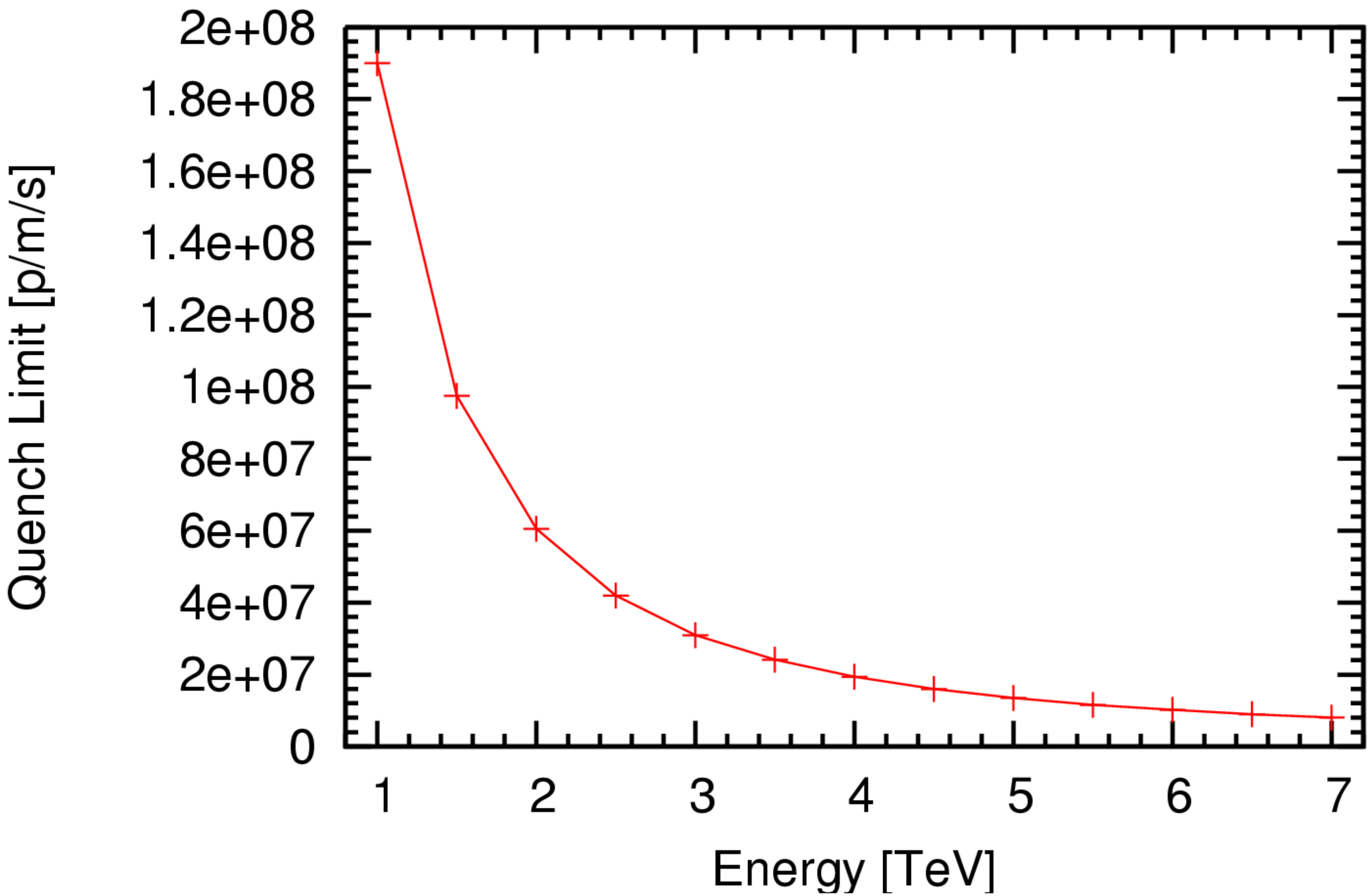
$$N_p^{\max} \geq \frac{\eta_c^{3.5TeV}}{\eta_c^{7TeV}} \cdot \frac{R_q^{7TeV}}{R_q^{3.5TeV}} \cdot \tau \cdot R_{loss}^{prim}$$

0.4 **0.29**

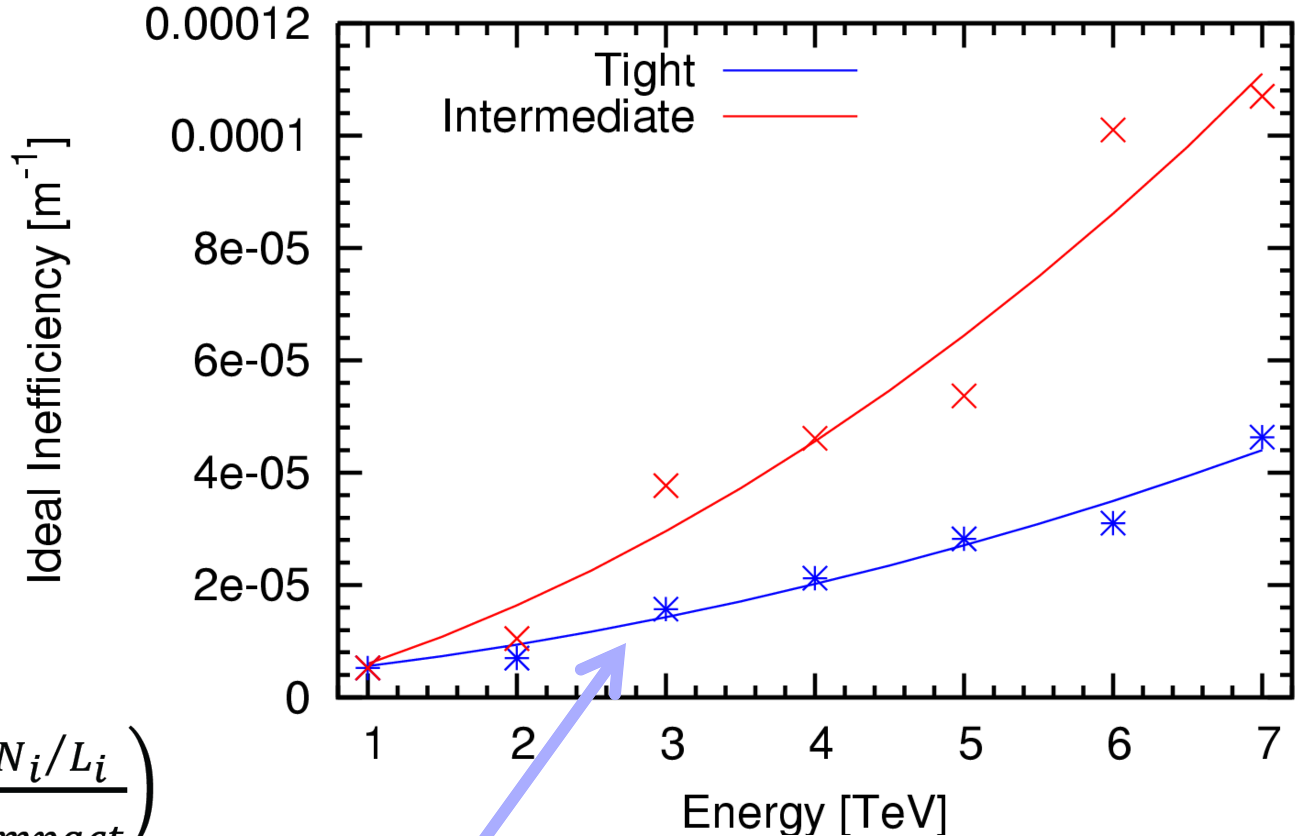
$$N_p^{\max} \geq 0.12 \cdot \tau \cdot R_{loss}^{prim} = 3.9 \times 10^{14}\, p$$

Tolerances ~shown, impedance ~OK for small emittance operation
Beta* lower than 1m not feasible with these settings (these are somewhat relaxed collimation settings).

Quench Limit vs Energy



Inefficiency versus Energy



$$\tilde{\eta}_{ineff} = \max_i \left(\frac{\Delta N_i / L_i}{N_{impact}} \right)$$

$$\frac{\tilde{\eta}_{ineff}}{10^{-4}} = 0.0276 \frac{1}{m} + 0.0231 \frac{1}{m} \cdot E + 0.0051 \frac{1}{m} \cdot E^2$$

Proton Performance Reach from MD: 7 TeV

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Extrapolated with MD2:

$$N_p^{\max} \geq 3.3 \cdot \frac{\eta_c^{3.5TeV}}{\eta_c^{7TeV}} \cdot \frac{R_q^{7TeV}}{R_q^{3.5TeV}} \cdot \tau \cdot R_{loss}^{prim}$$

0.4 **0.29**

$$N_p^{\max} \geq 0.4 \cdot \tau \cdot R_{loss}^{prim} = 1.3 \times 10^{15}\, p$$

Requires collimation at 4 sig_nom with tighter tolerances than nominal. OK for nominal beta*.
Tolerances not achieved (we tried in MD1), impedance only OK for large emittance operation.

FLUKA for p Performance Reach

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- Can give detailed power deposition.
- Simulation for perfect machine. No imperfections (orbit, beta beat, misalignments, …).
- Predicted 3.5 TeV energy deposition:
  - Deposit **11 mW/cm^3** (relaxed collimation settings, MD1 loss: 9e11p/s)
  - Quench limit: **5.5 – 41 mW/cm^3** (latest estimate islargest)
- Predicted 7 TeV energy deposition:
  - Deposit **4 mW/cm^3** (tight collimation settings, **0.2h** lifetime: 4e11p/s)
  - Quench limit: **2 – 15 mW/cm^3** (latest estimate is largest)
- Results consistent with no quench.
- Results consistent with p performance reach estimate.
- Detailed reach depends on quench limit, collimation settings, lifetime (better), imperfections (worse), …

Ion Performance Reach

- Analyzed with ion lifetimes and taking into account MD results.
- Prediction for 7 TeV equivalent:
  - **50% of nominal ion intensity**