Brief recap of machine protection studies: modified TCDD vs complementary mask in D1 insulation vacuum

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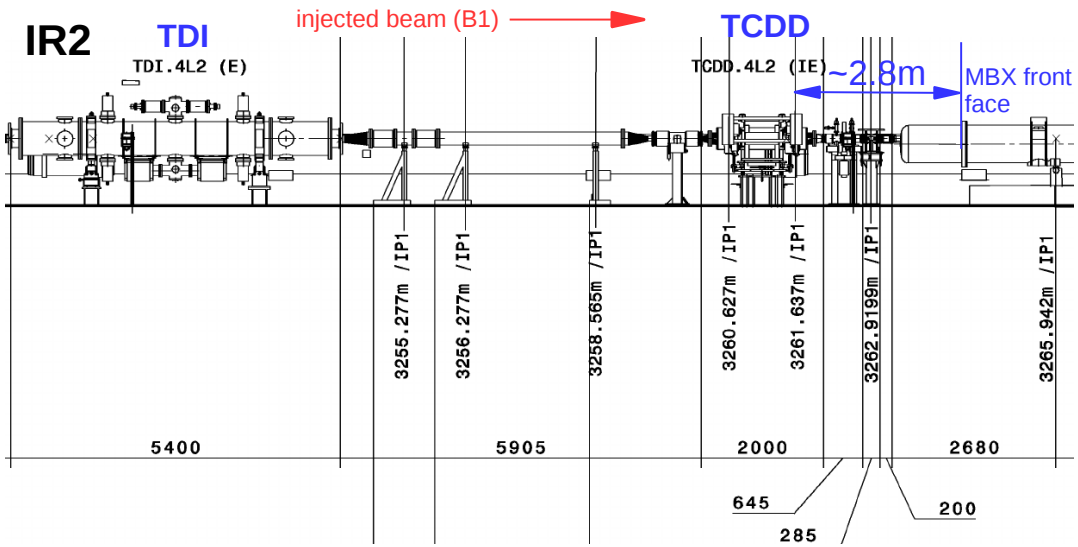
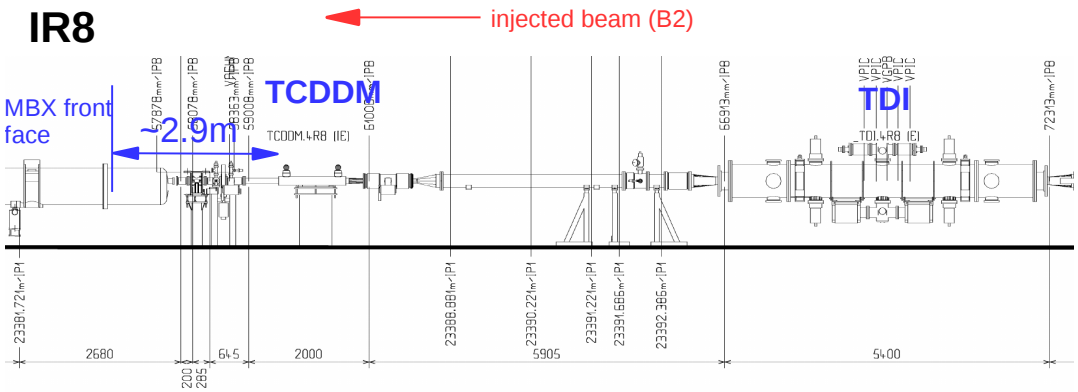
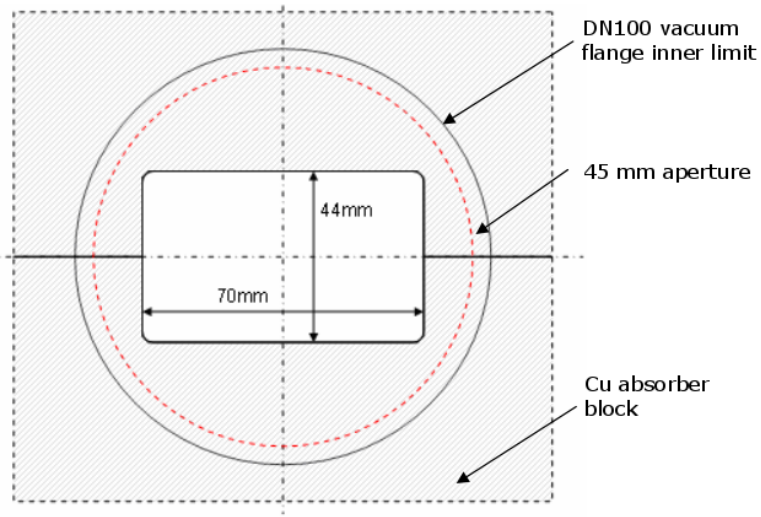
Present TCDD position and aperture

- Present TCDD(M):
  - $70 \times 44\,\mathrm{mm}^2$ (D1 aperture: r=40 mm)
  - TCDD end – D1 front ≈2.8 m





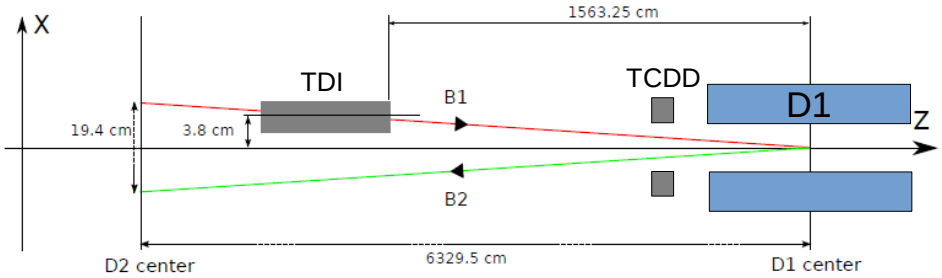


IR2:

IR8:

Asymmetric shielding

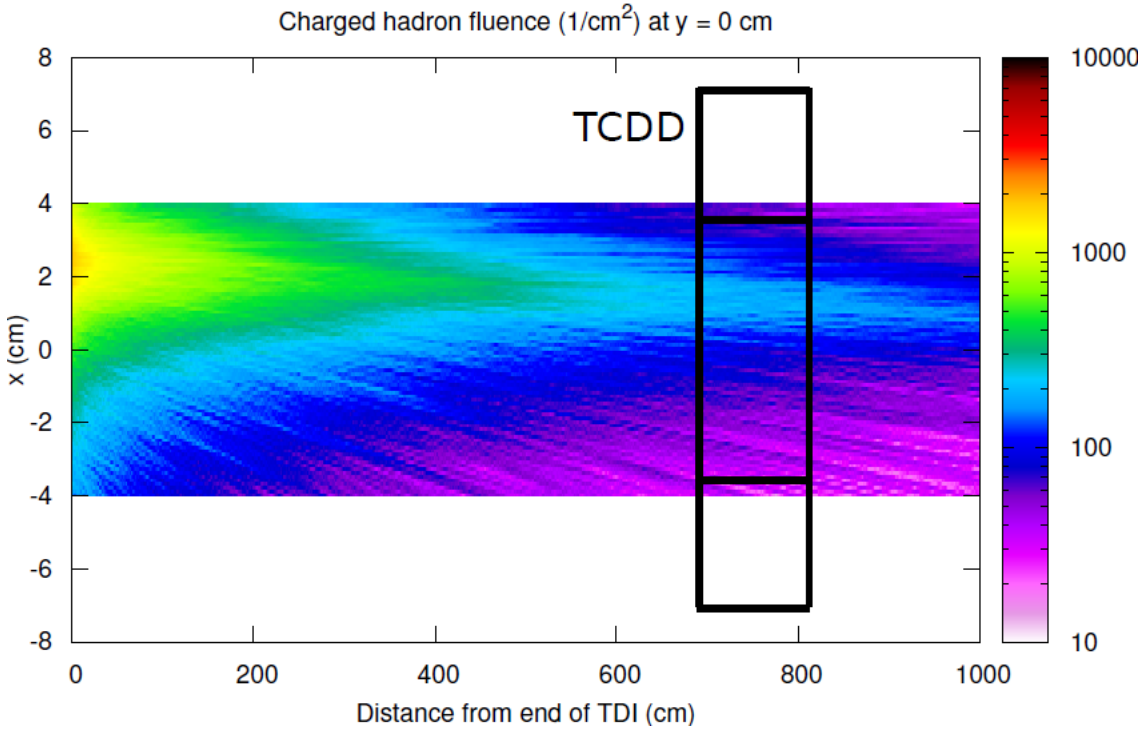
TDI located between separation dipoles:

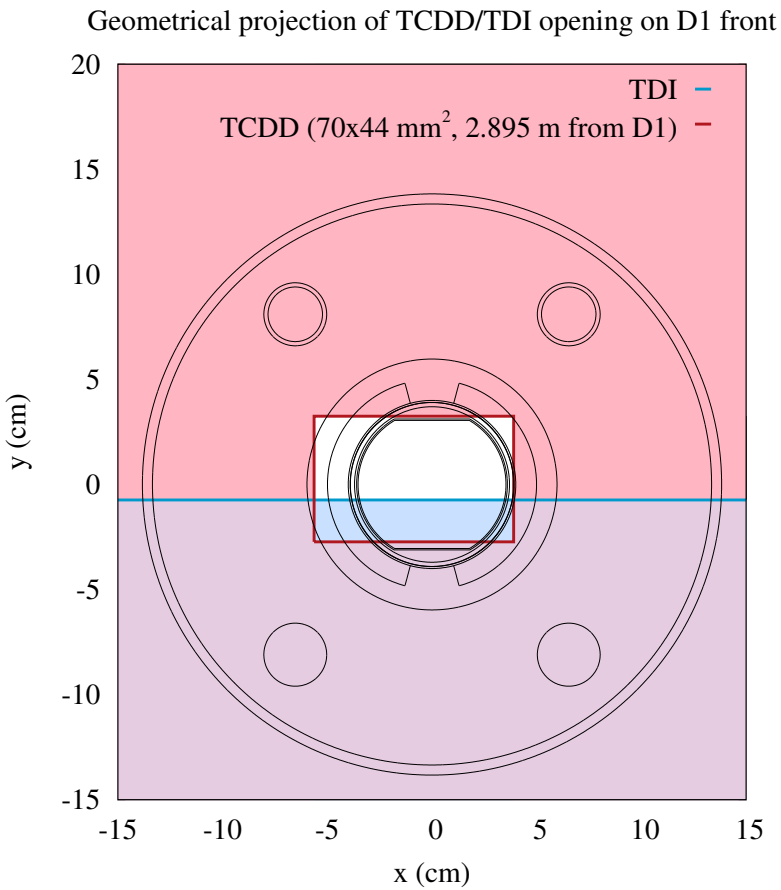


→ Beams have a horiz. angle of ∼1.5 mrad

→ TCDD opening sym. around machine axis

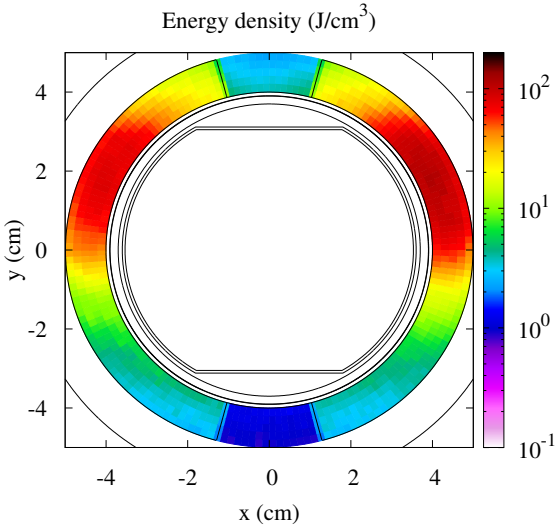
→ Provides asym. protection of D1 coils



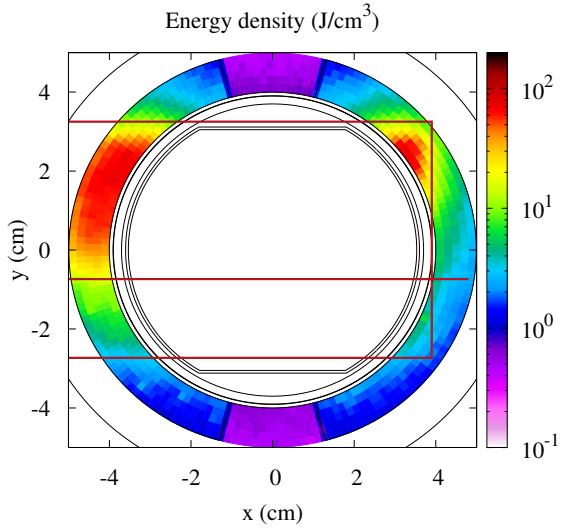


Small impact parameter ($\sim \sigma$) on TDI: effectiveness of the present TCDD (IR2)

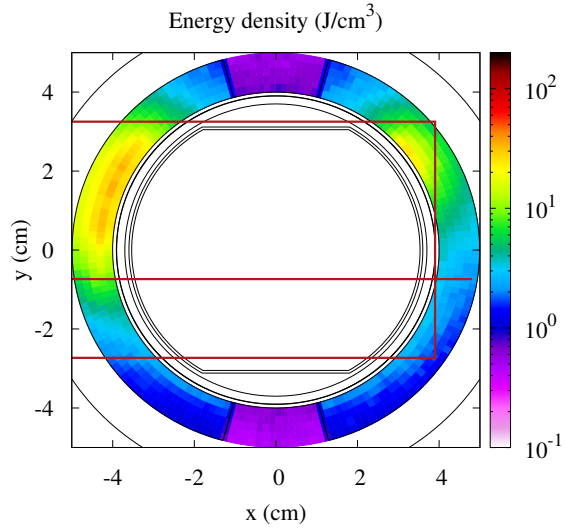
No mask:



Present mask:



Present mask+vacuum tubes:



Figures: Transverse energy density profile at longitudinal maximum in D1 coils, for 288 bunches (2.3×10^{11} ppb) impacting on lower TDI jaw with an impact parameter of 1σ. No mask (left), present TCDD (center), and present TCDD + vacuum modules/transition tubes between TCDD and D1 (right).

The simulation results suggest:

- Mask does not reduce much the load on D1 coils at inner side of the ring (@negative x)

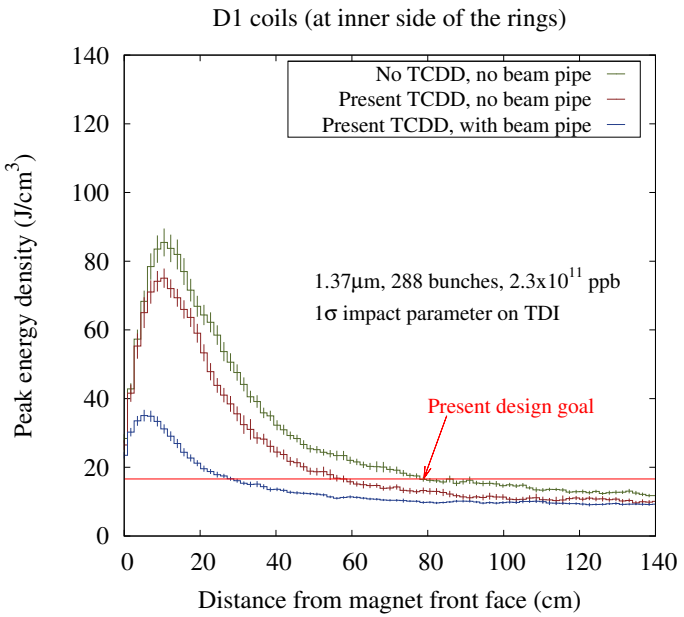
  $\rightarrow$ due to asymmetry, quite large mask aperture, and large distance from D1 front face

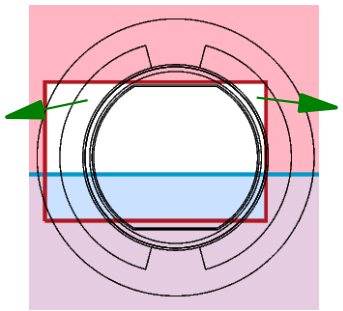
- Significant shielding by vacuum modules and cold-warm transition tube

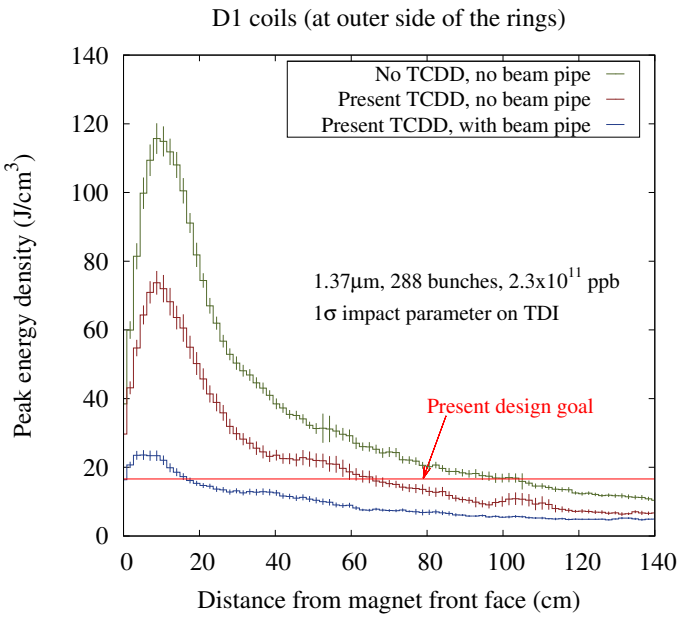
  $\rightarrow$ yields a factor $\sim$2–3 reduction compared to case with TCDD only

  $\rightarrow$ results depend on details of FLUKA geometry model of vacuum layout

Small impact parameter ($\sim \sigma$) on TDI: effectiveness of the present TCDD (IR2)







- Design goal: energy density in D1 coils $\leq$ assumed damage limit $\times$ 1/3 (the latter is a safety factor for energy deposition calculations)
- Considering the present knowledge of the damage limit, we aim in reducing the energy density by about a factor two

Ideally, should find a solution where we depend less on shielding by vacuum equipment

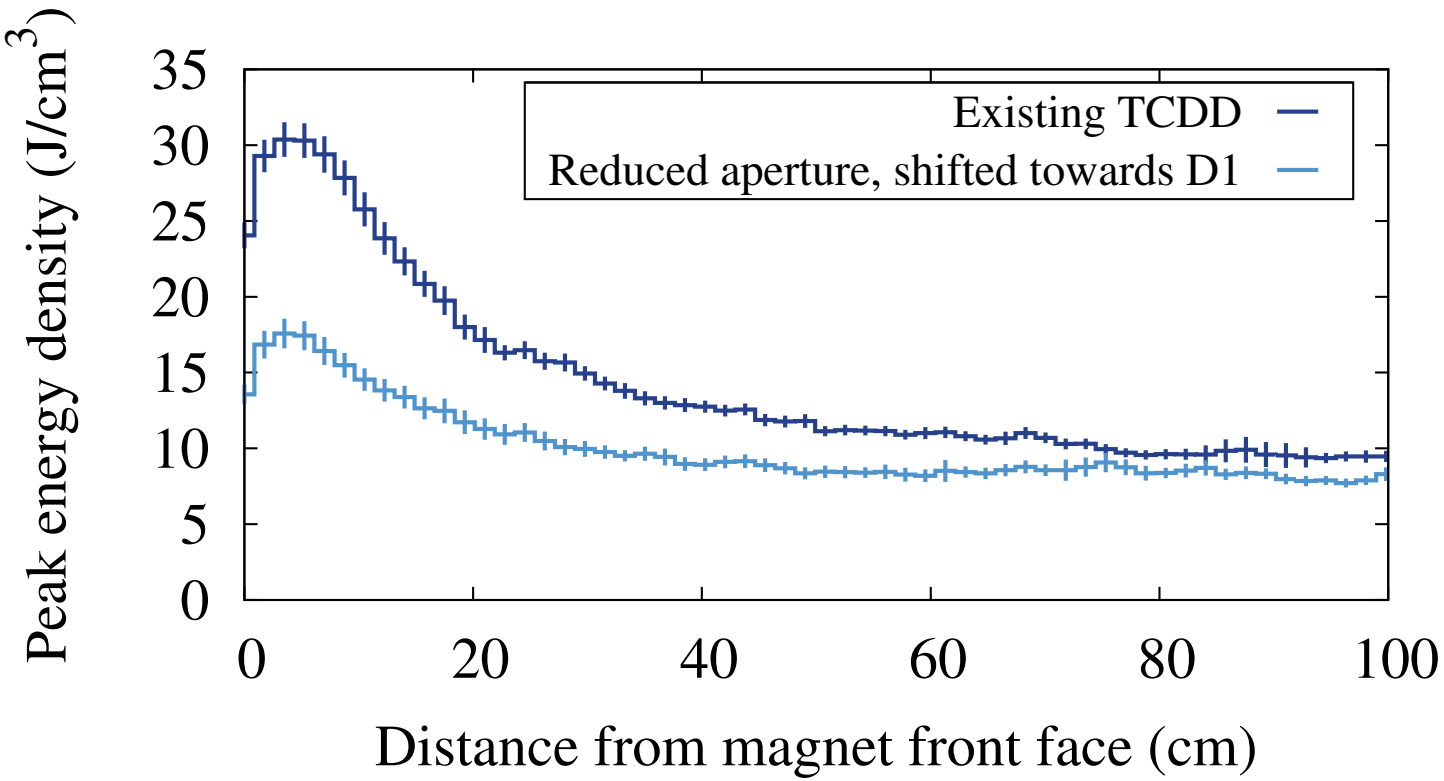
How could we reduce the energy density in D1 coils? Presently we consider two options:

$\rightarrow$ *Reduction of TCDD aperture + moving mask closer to D1*

$\rightarrow$ *Complementing present TCDD with another passive protection element inside D1 insulation vacuum*

Option 1: Reduction of TCDD opening + moving TCDD closer to D1

- TCDD opening can only be reduced by some mm on each side due to circ. beam apertures (different optimization for IR2 and IR8)
- Max. possible longitudinal shift: ∼60 cm (requires displacement of BPM)
- One could in principle reach the required reduction of the energy density in D1 coils



Option 2: 15–18 cm long higher-Z mask inside D1 insulation vacuum

- 1 cm thick mask clamped around cold bore protruding from cold mass assembly
- TCDD would be kept as it is (prerequisite: no TCDD material upgrade needed for robustness reasons → just confirmed by thermo-mechanical studies)
- Due to the proximity to magnet front face, one can effectively protect the D1 coils (slightly better reduction than Option 1)