SAND2007-3993C

MODELING OF A COMPACT PULSER FOR ISENTROPIC COMPRESSION EXPERIMENTS*

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* Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy under Contract No. DE-AC04- 94AL85000.

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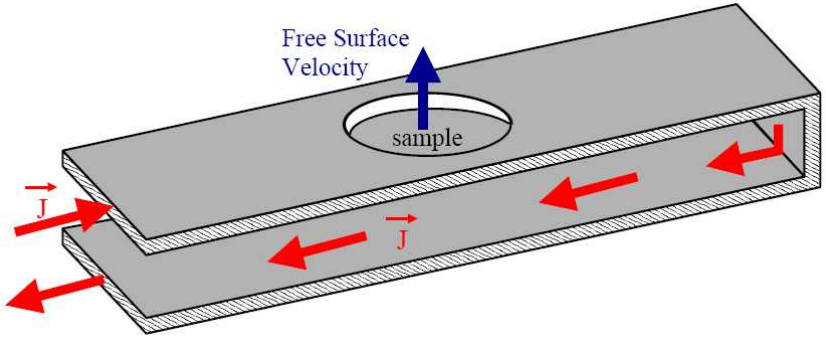
VELOCE – a compact electrical pulser for isentropic compression and shock physics experiments

- Strip line configuration
- Peak current: 3.5 MA
- 10 – 90% rise time: 350 ns
- Small size: 6.6 m x 5.5 m
- Kapton / Mylar insulation (no water, oil, vacuum for insulation)
- Easy to operate → fast turn around
- Low operational cost

$$P_{mag} = K_l \cdot \frac{\mu_0}{2} \left(\frac{I}{w}\right)^2$$



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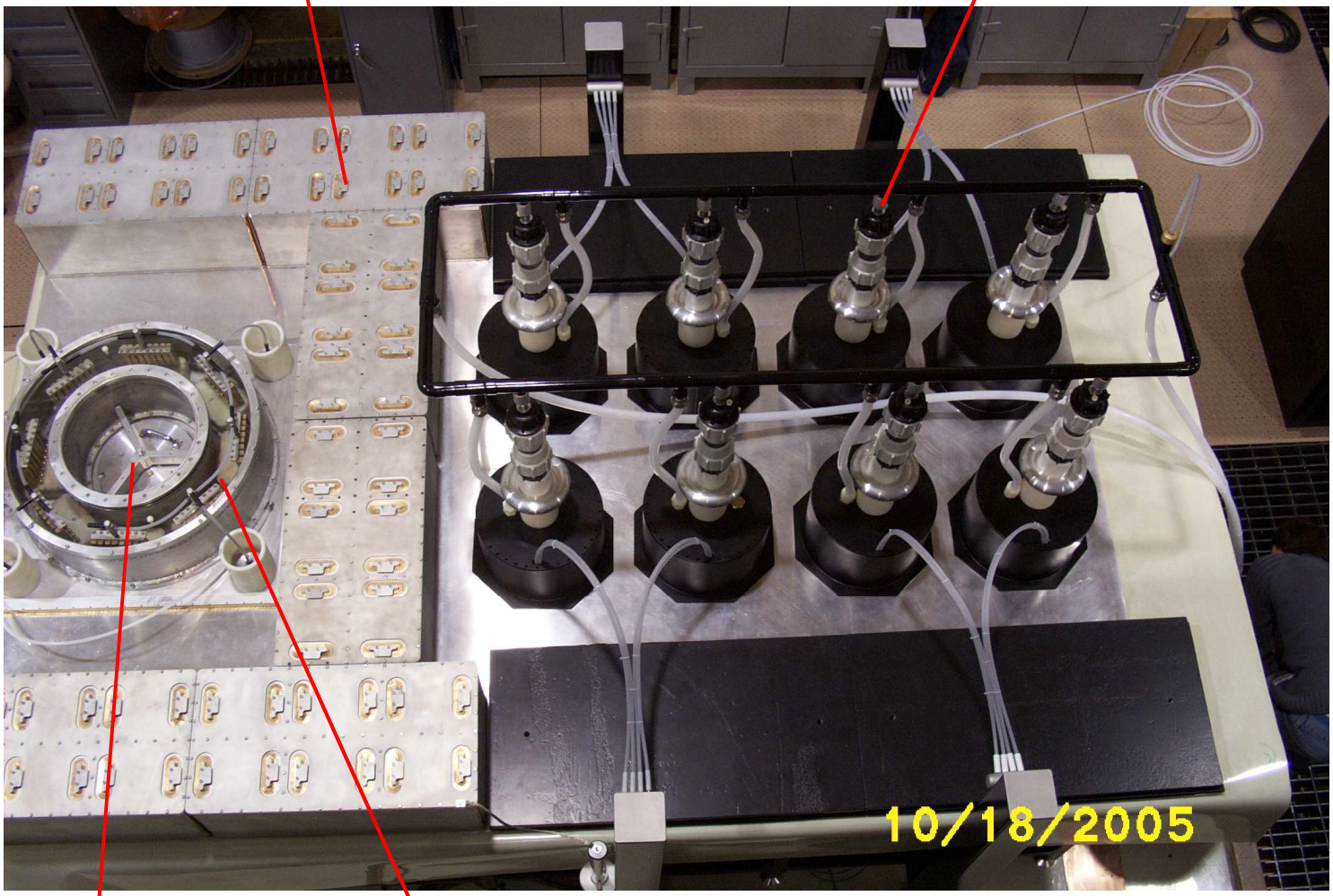
VELOCE

48 peaking capacitors

8 main capacitors



Load chamber

Dynamic Switch

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ALEGRA: a Magneto Hydrodynamic Code

- Arbitrary Lagrangian-Eulerian finite element 2-D and 3-D code
- Includes:
  - Magneto hydrodynamics (MHD)
  - Thermal conduction
  - Radiation transport
  - Material models
- Coupled with large number of material data (equation of states, opacity tables…)

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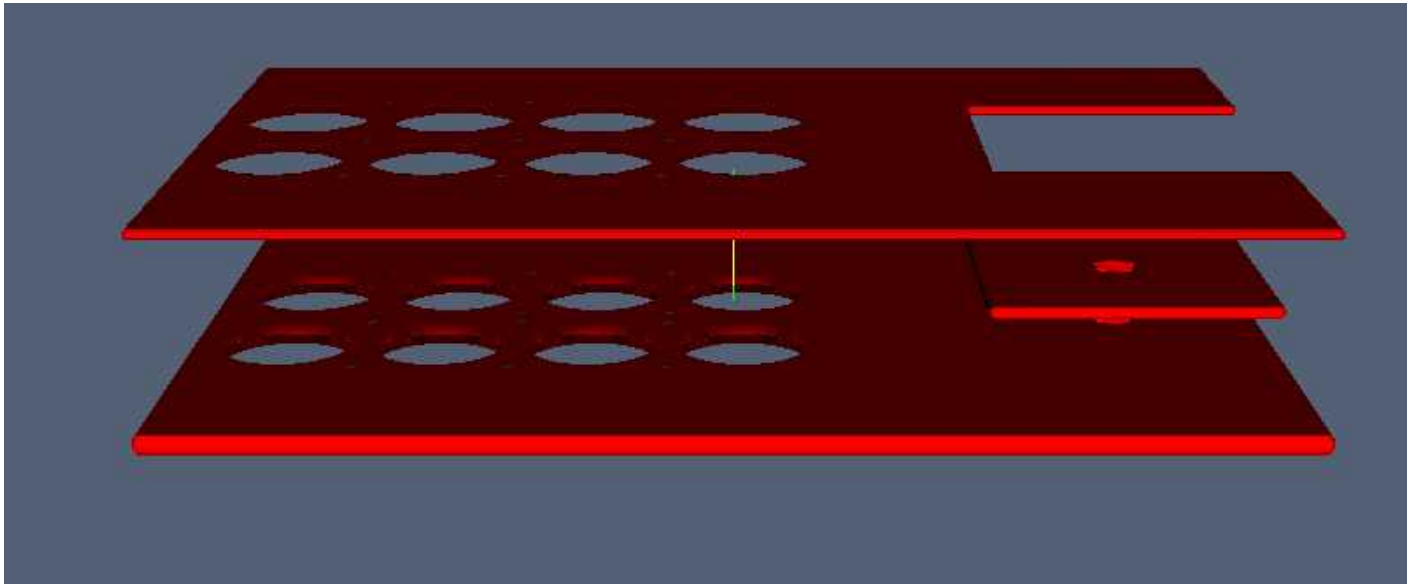
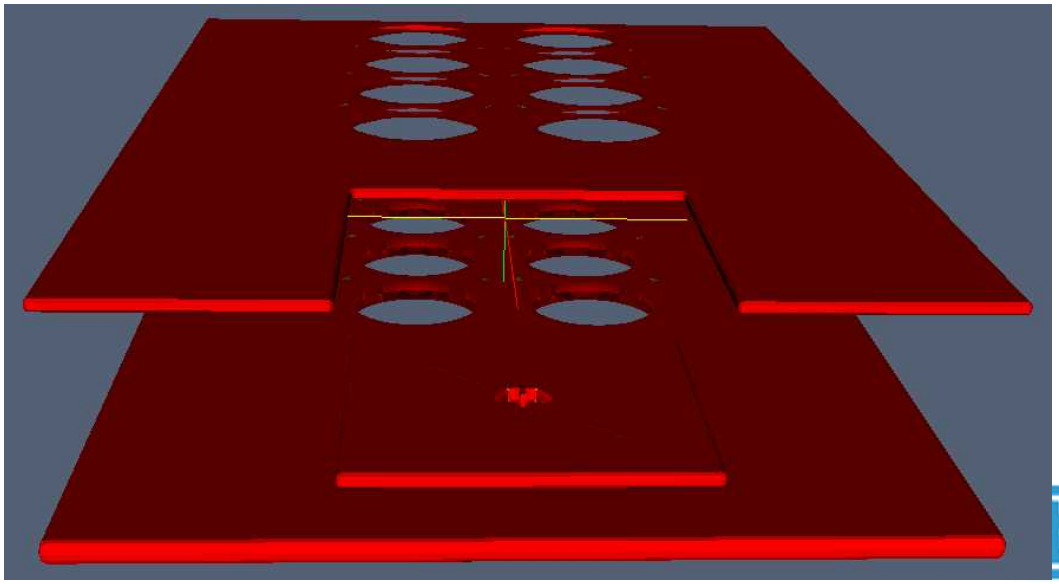
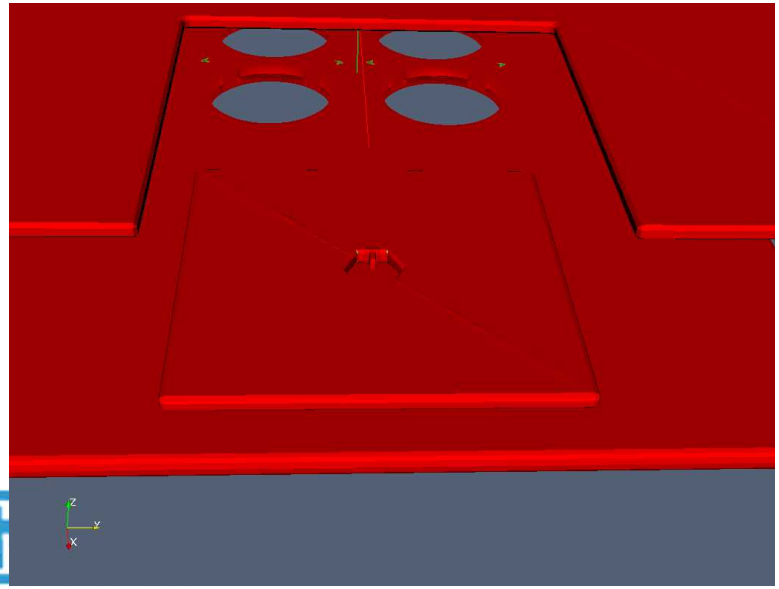
Modeling of Veloce pulser

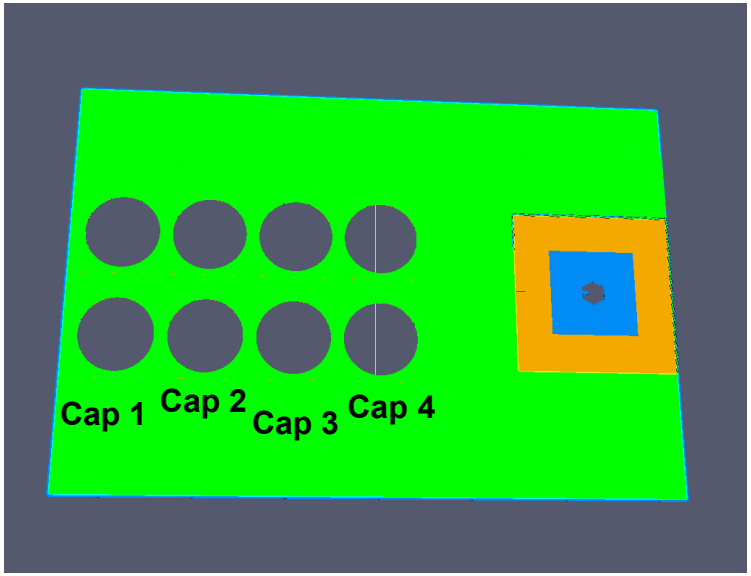


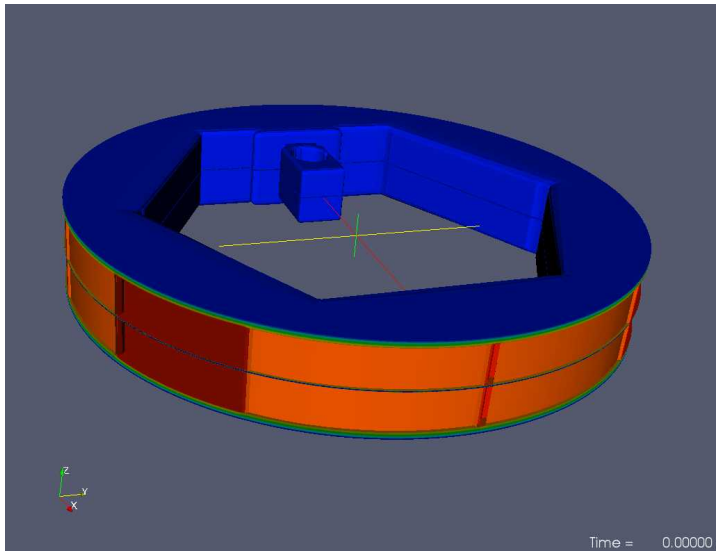


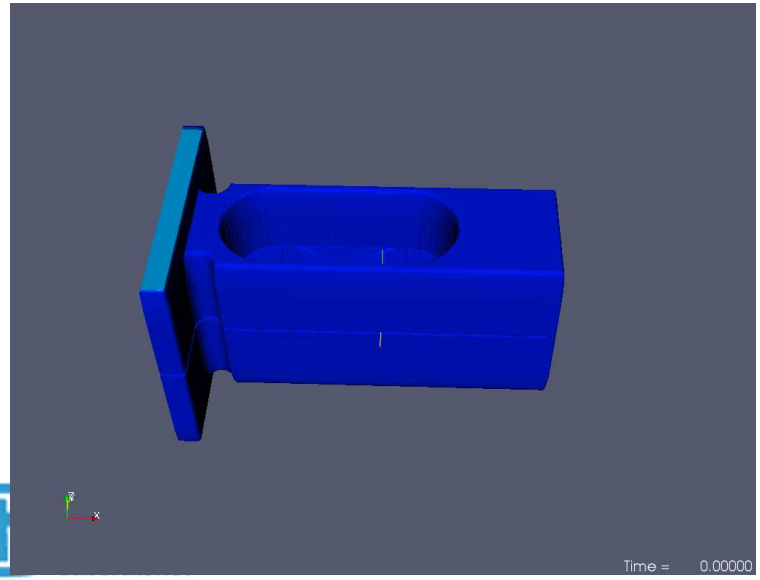


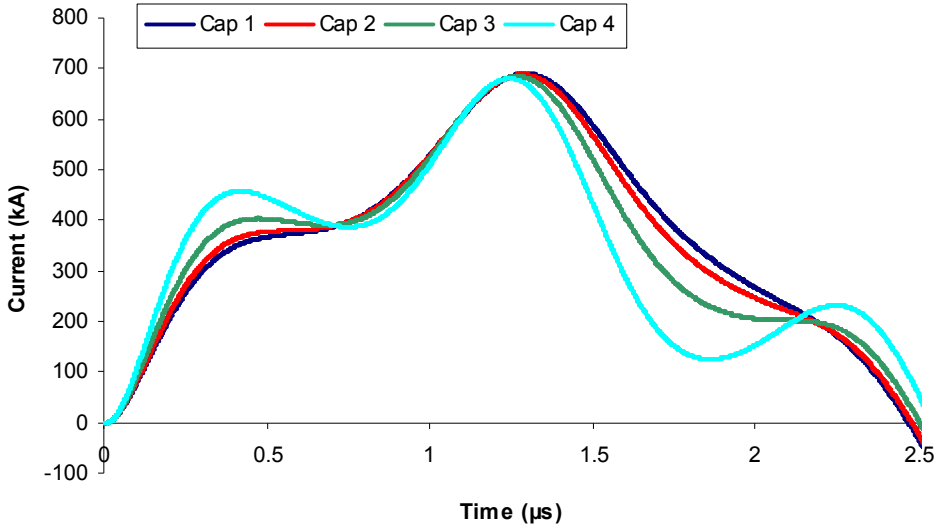
VELOCE MHD Simulations

Goal: optimize current uniformity of the sample panel

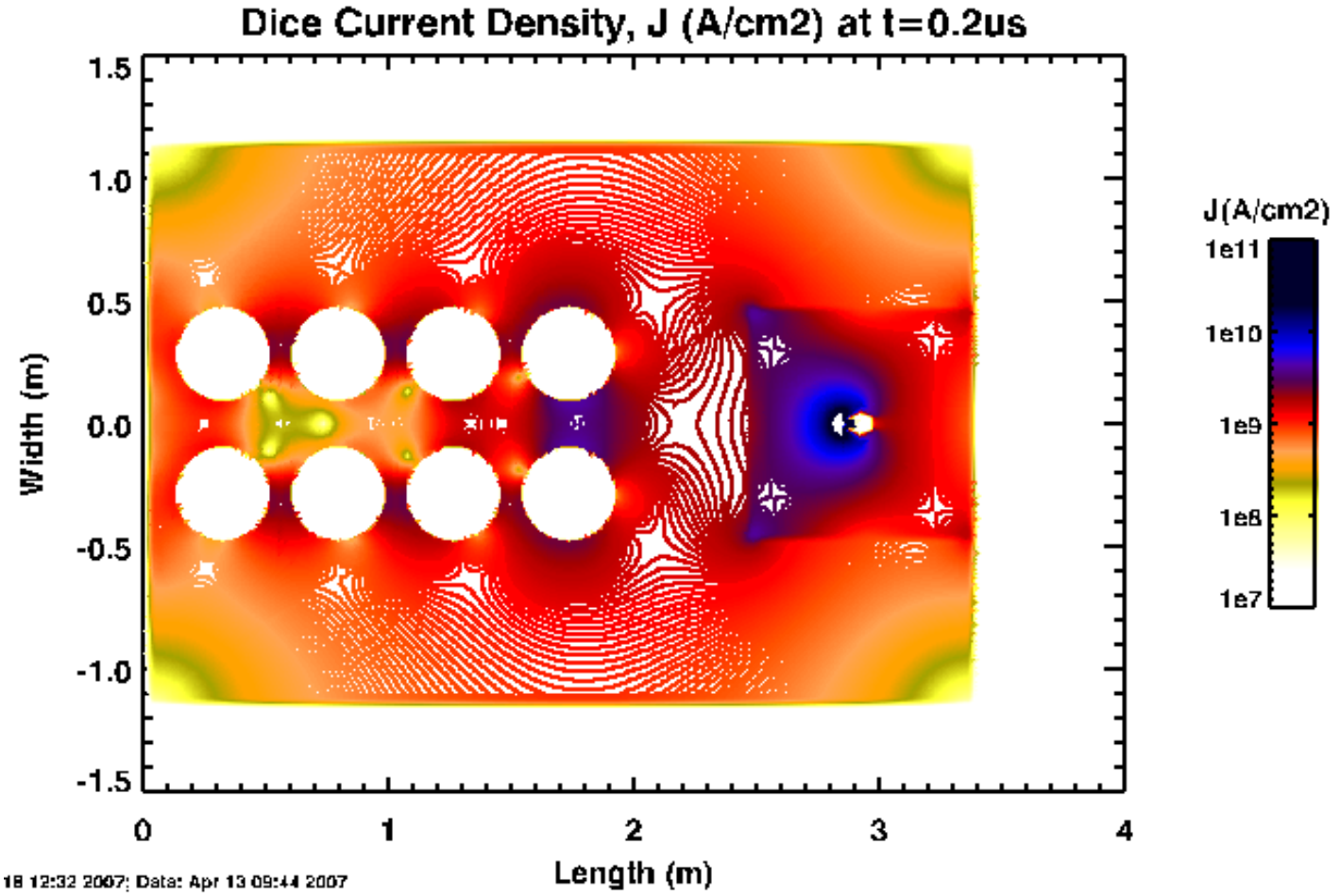








VELOCE Simulations: full machine



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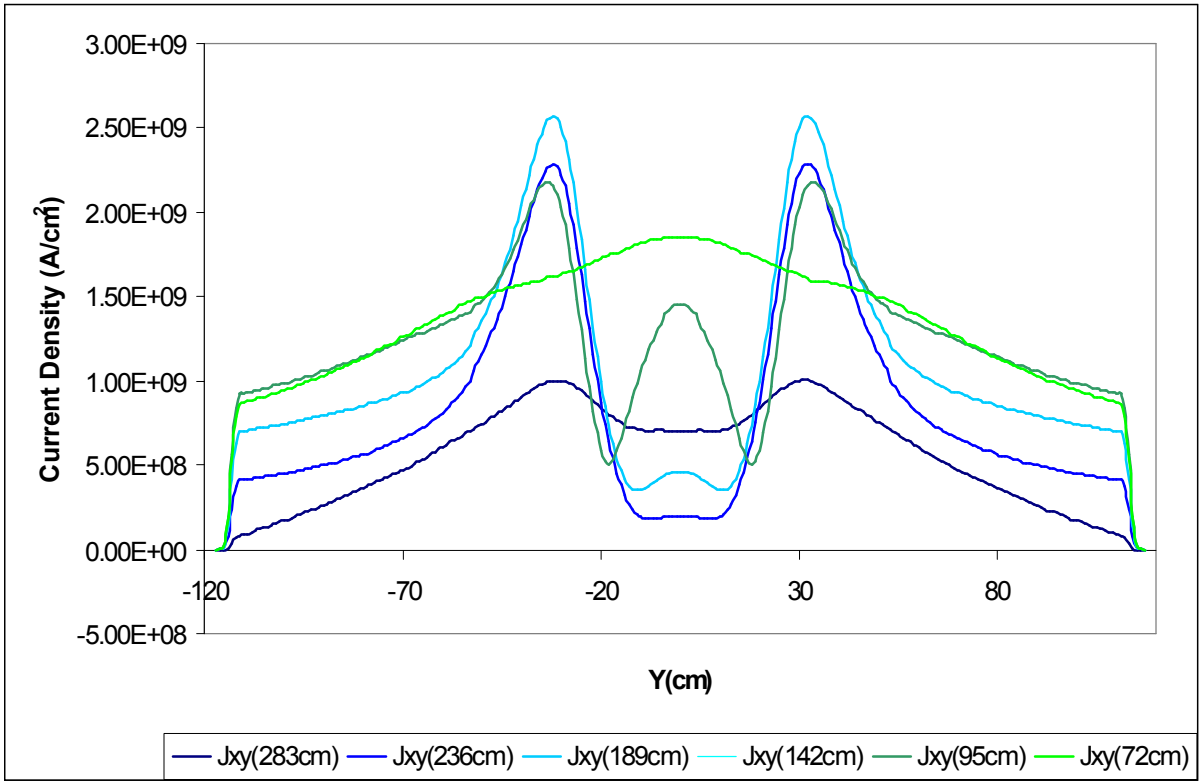
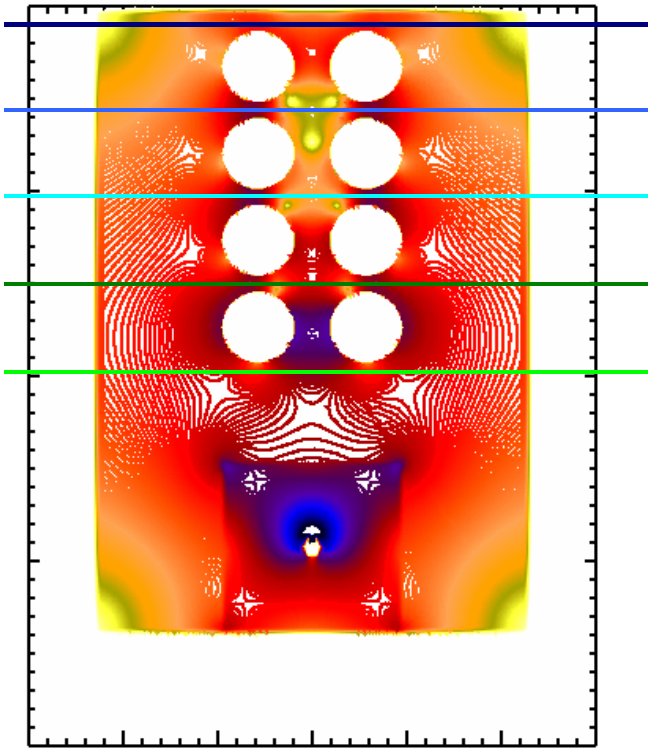
VELOCE Simulations: Full machine

Current density distribution across the width as function of distance from the load





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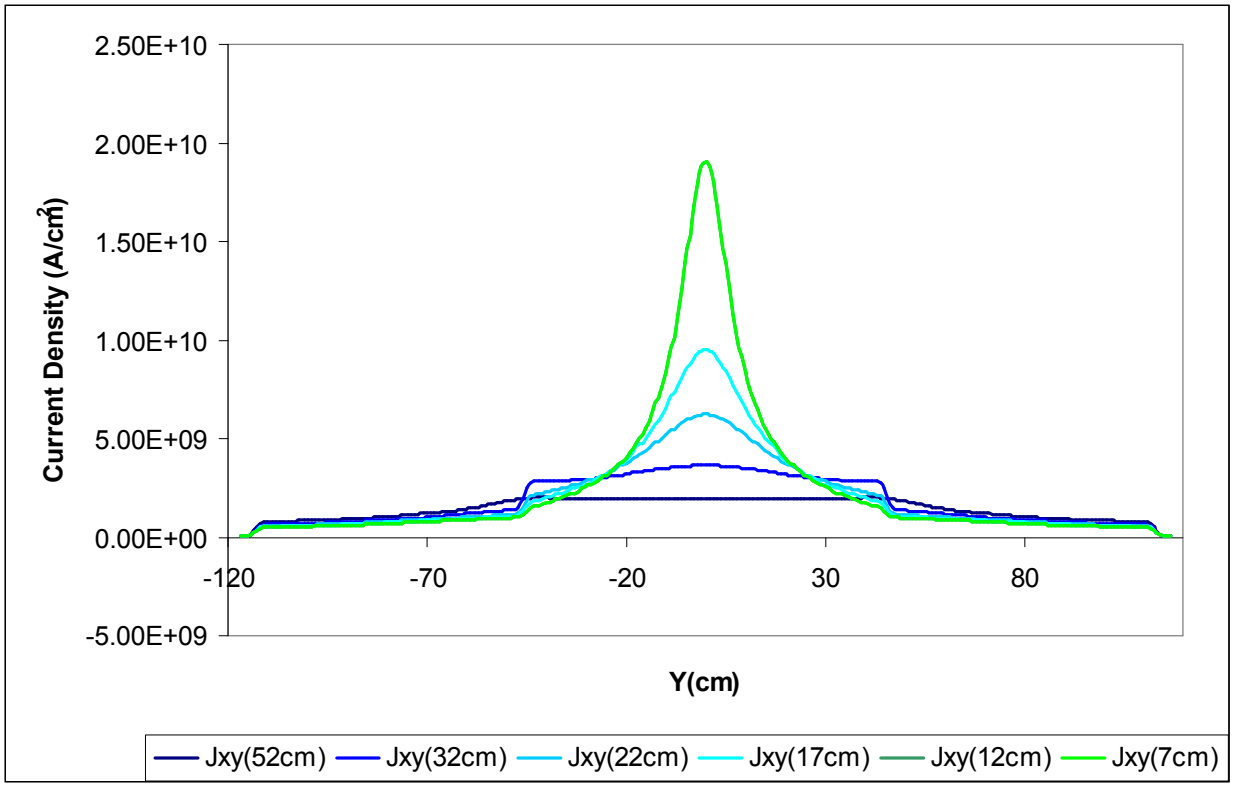
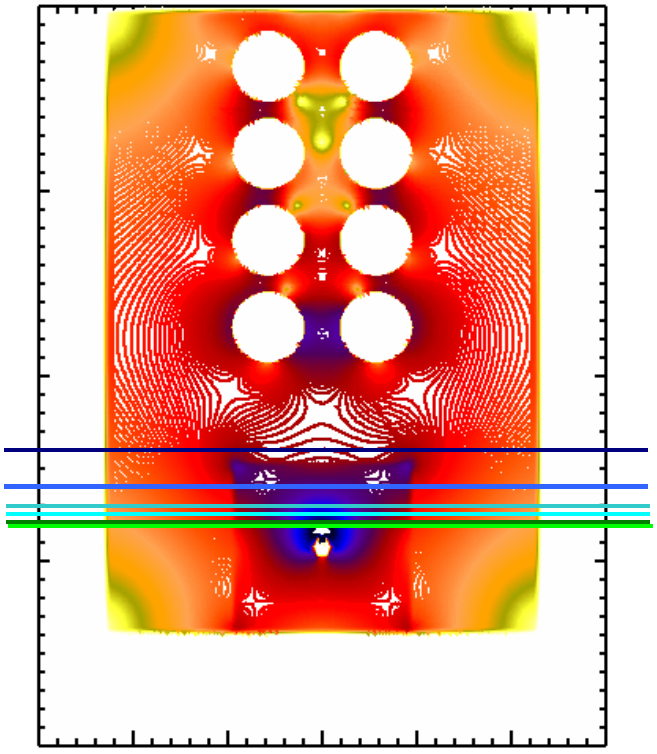
VELOCE Simulations: Full machine

Current density distribution across the width as function of distance from the load





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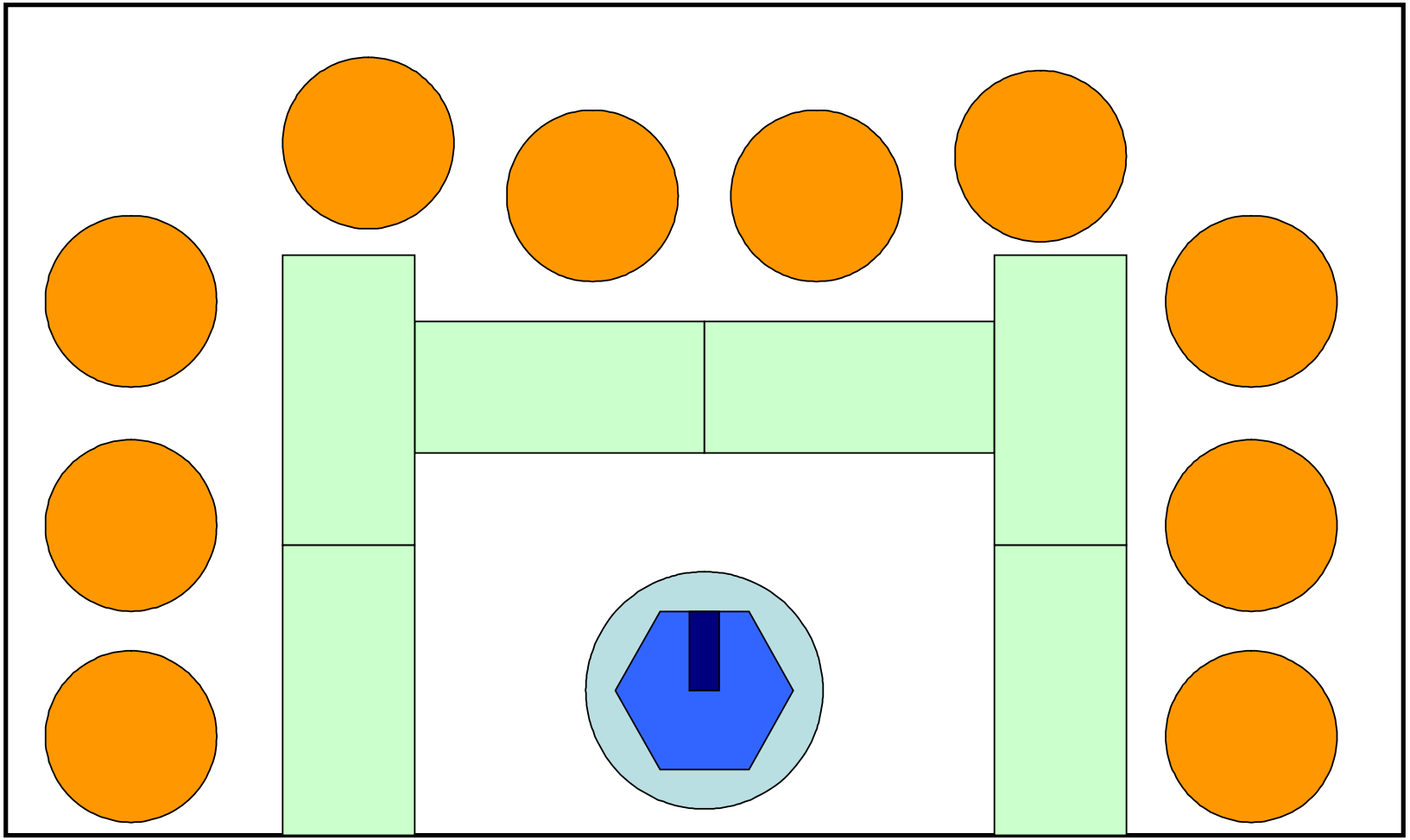
VELOCE Uprade: Proposed Design

- Redistribute main capacitors around peaking capacitors
- Add 2 or 4 main capacitors

→ Increase the current by ~20 %



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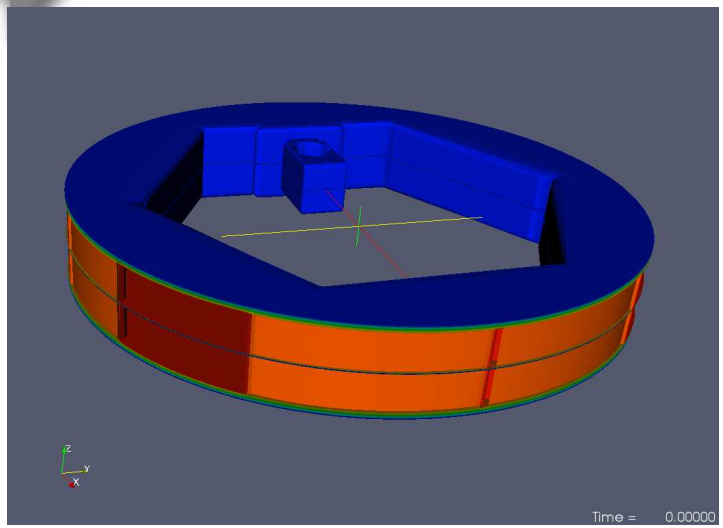
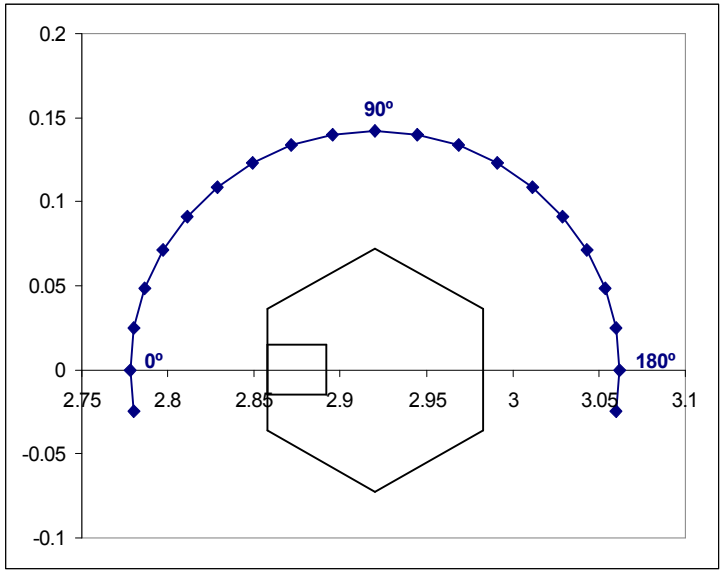
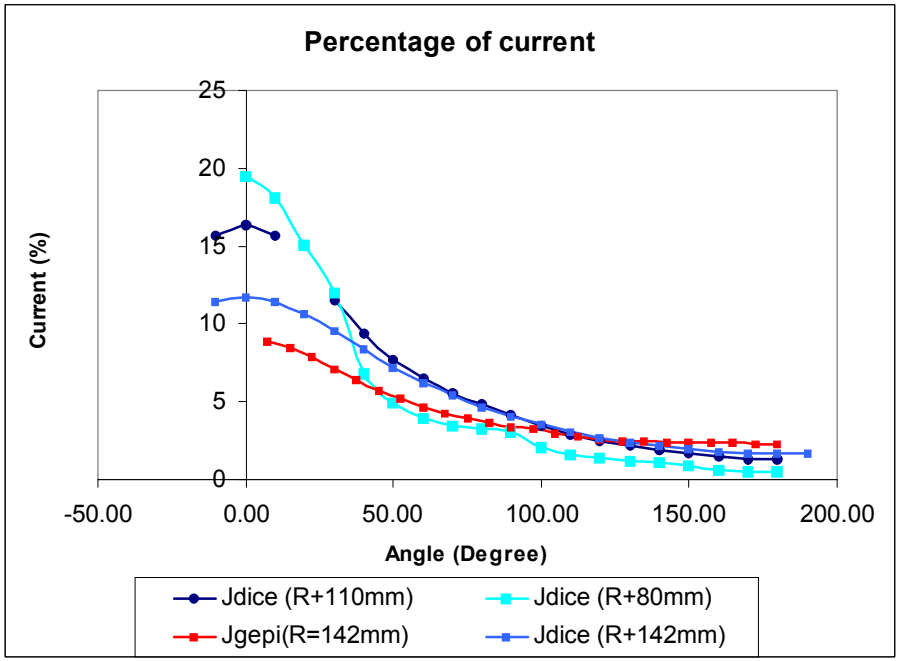
VELOCE Simulations: Load Area



Circular boundary: input current distribution from whole Veloce simulation
Current distribution more favorable than for the French machine GEPI





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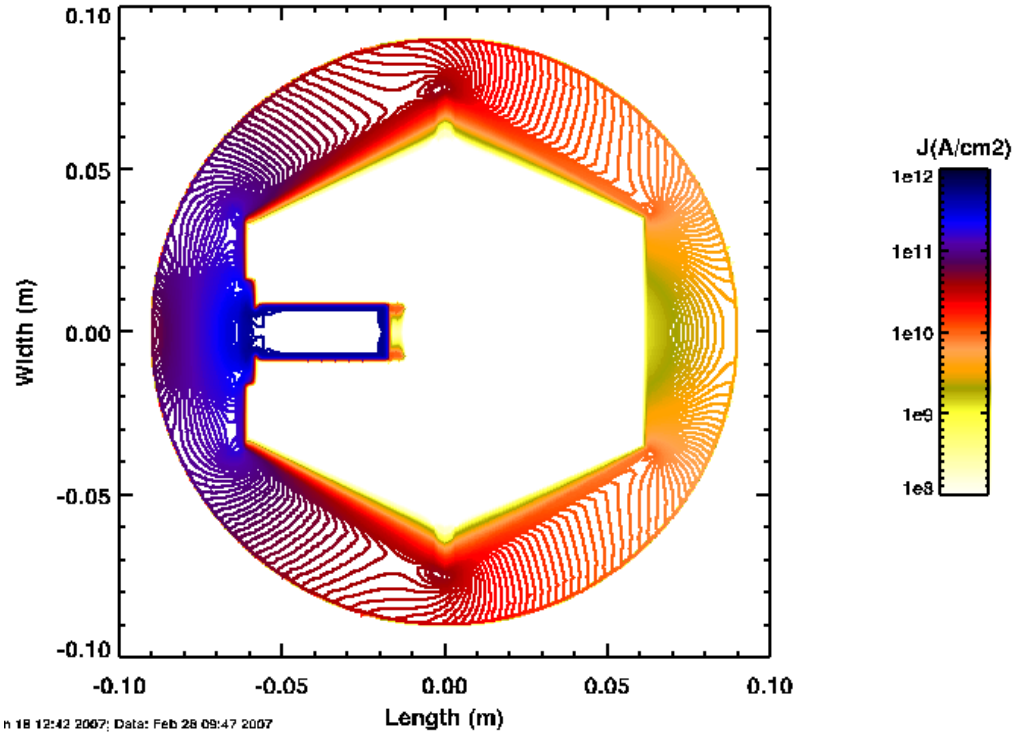
VELOCE Simulations: Load Area

Most of the current distributed on side of the panel



- Resolution limited because of size of simulation → Simulation of panel
- Input current distribution for panel simulation provided by whole load area simulation

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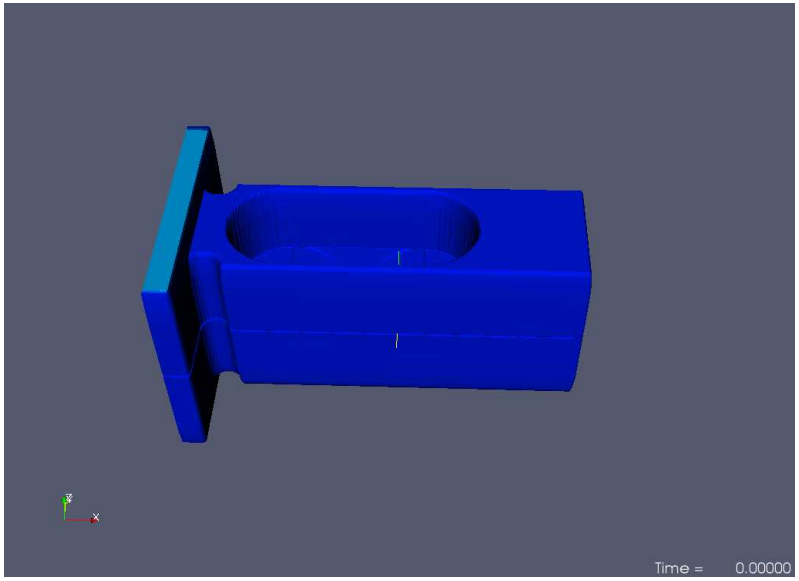
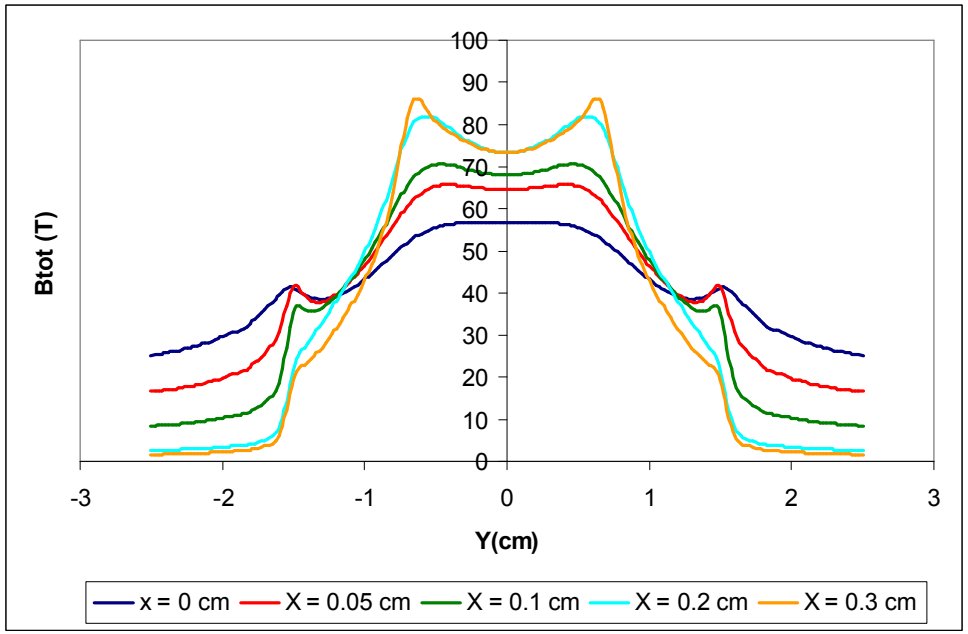
VELOCE Simulations: Panel Area



Input current distribution for panel simulation



Resolution :

- 0.25 mm in X and Y direction (panel plane)
- 0.0425 mm graded to 0.25 in z direction

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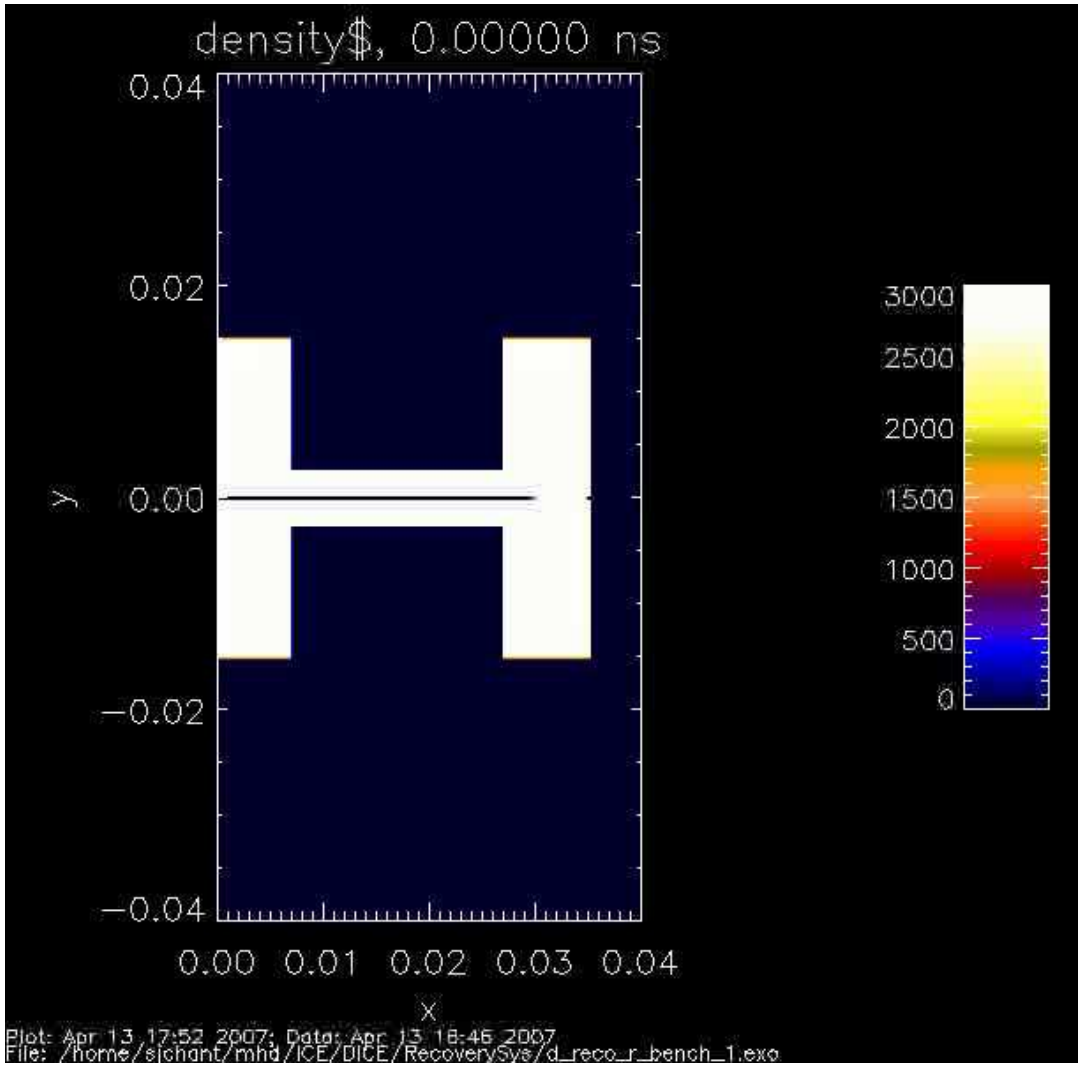
VELOCE Simulations: Panel Area

Density profile as a function of time



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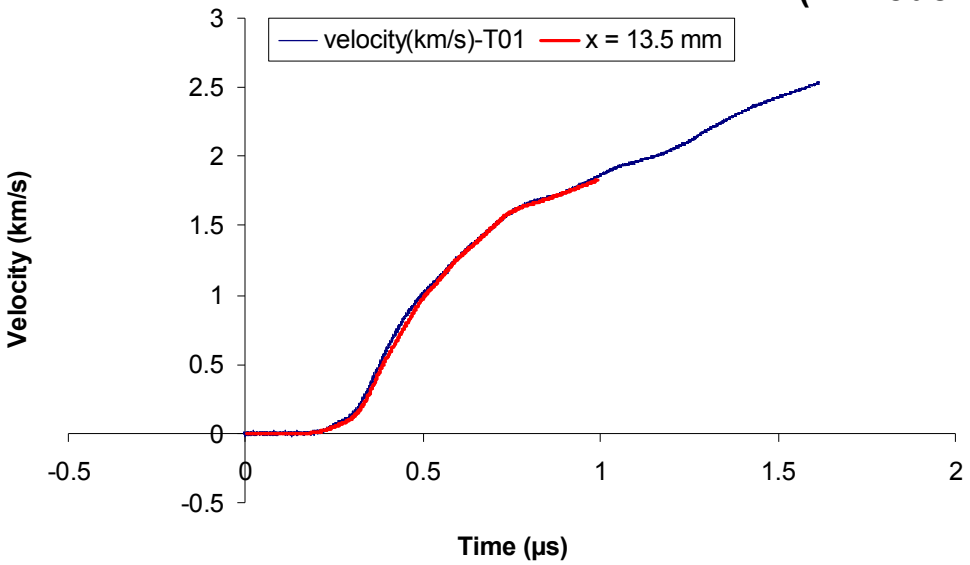
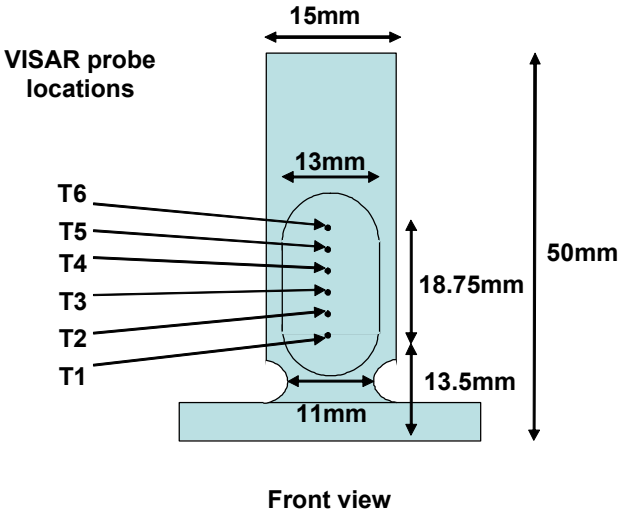
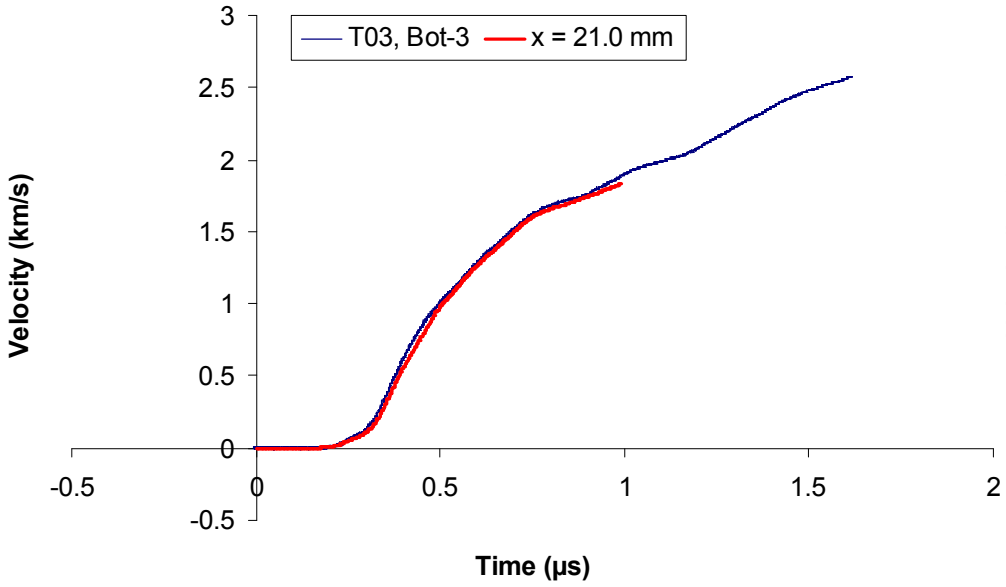
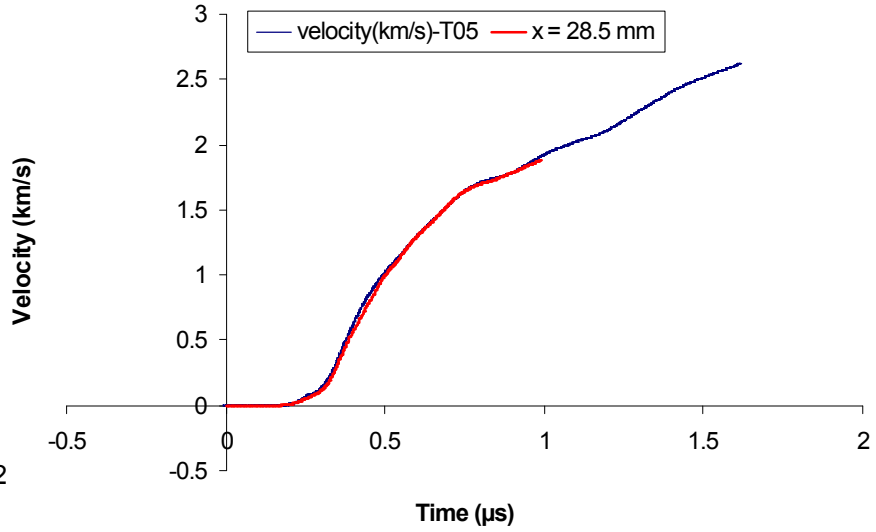
VELOCE Simulations Benchmarking

Comparison of measured and calculated free surface velocity at different probe positions
(– model – experiment)









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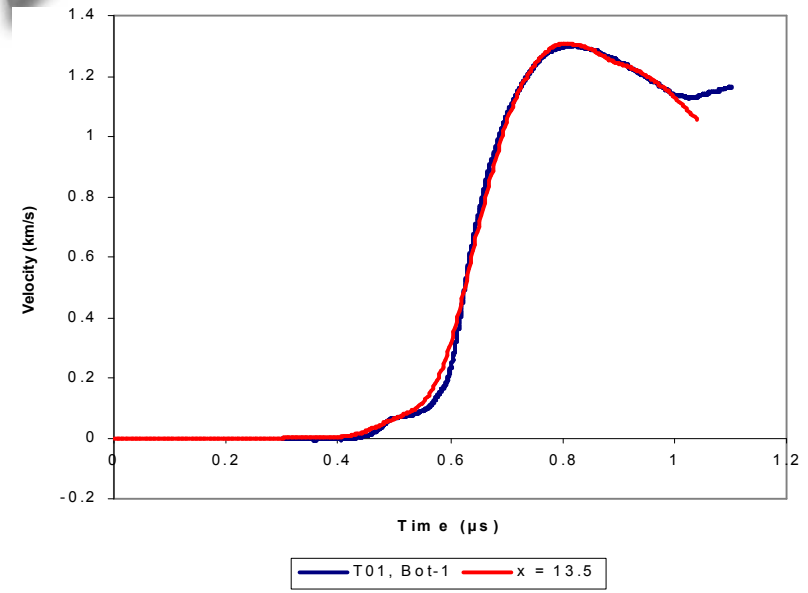
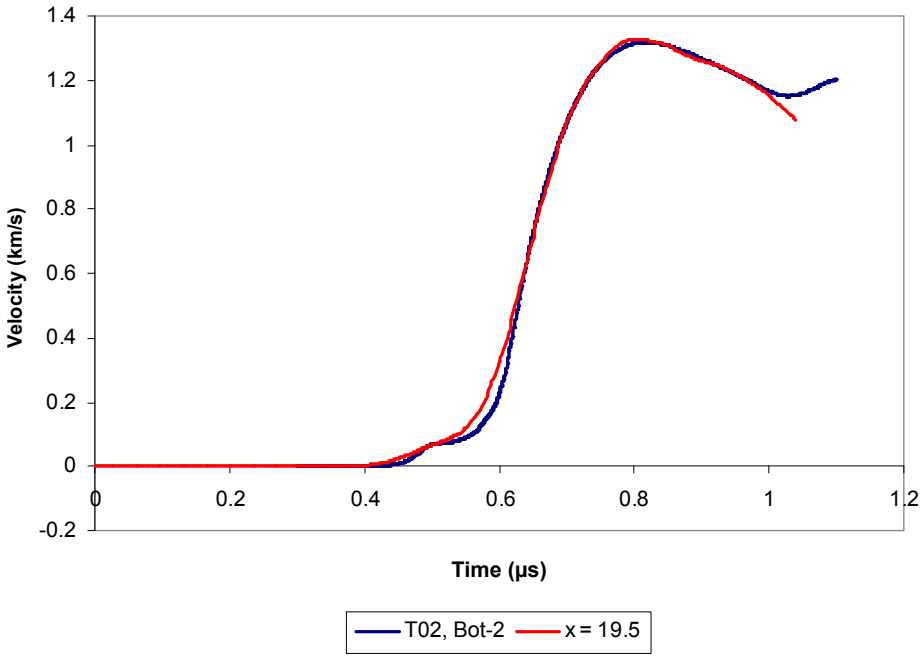
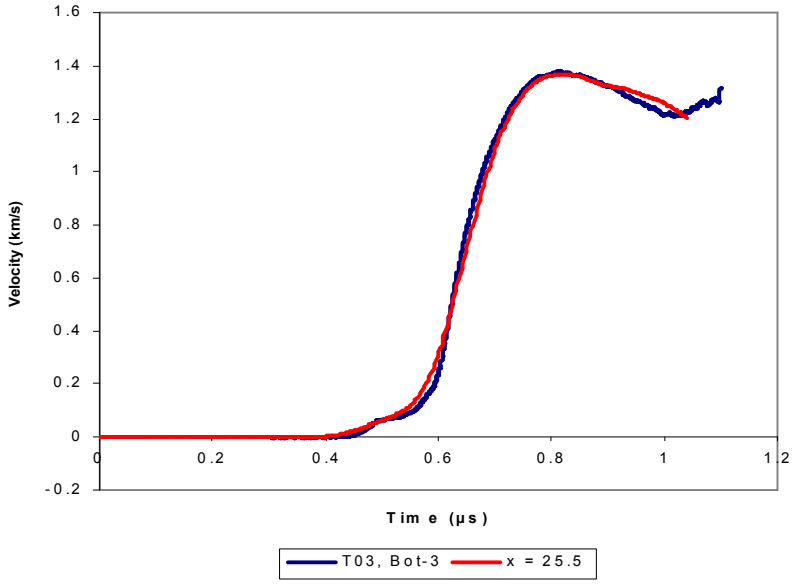
VELOCE Simulations: Panel Area

Reference Panel: free-surface velocity curves







Simulation and experimental free-surface velocity as a function of time at three positions along the length of the panel : 13.5 mm, 19.5 mm and 25.5 mm.

Reference panel: 15 mm x 35 mm x 2.5 mm

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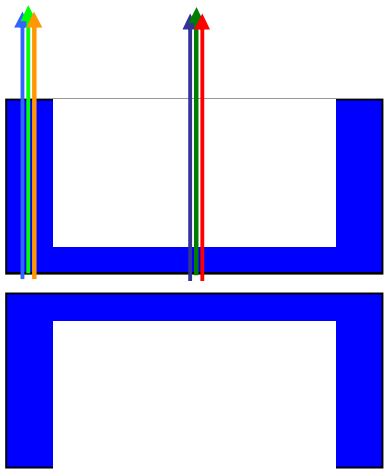
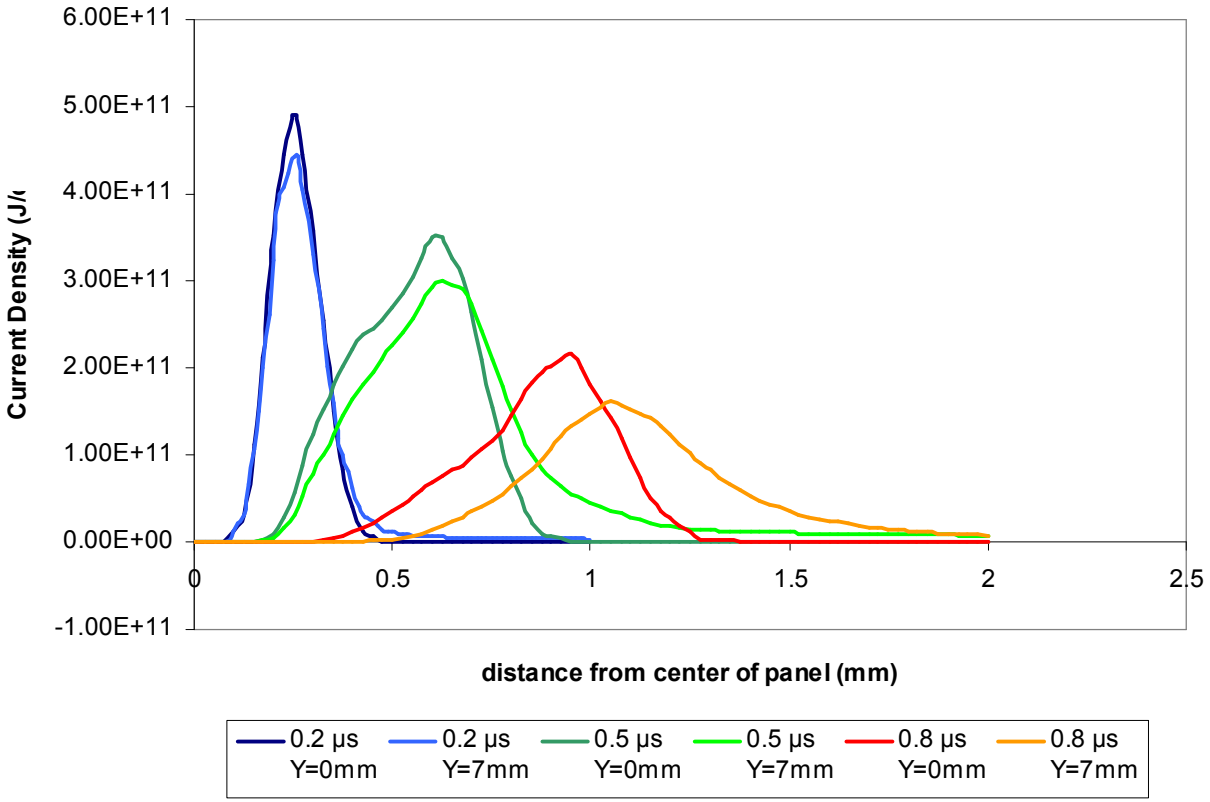
VELOCE Simulations: Load Area Current Diffusion in the Panel





Total current density across the thickness of the panel at 2 cm from the bottom of the panel at three different times: 0.2 μs (blue curves), 0.5μs (green curves) and 0.8 μs (red-orange curves). The current density is estimated in the center of the panel width (Y=0 mm) and at the edge of the panel width (Y=7mm).

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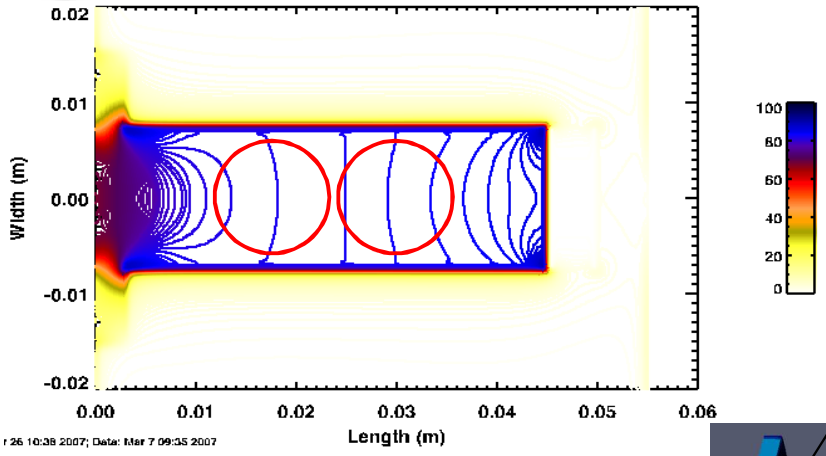
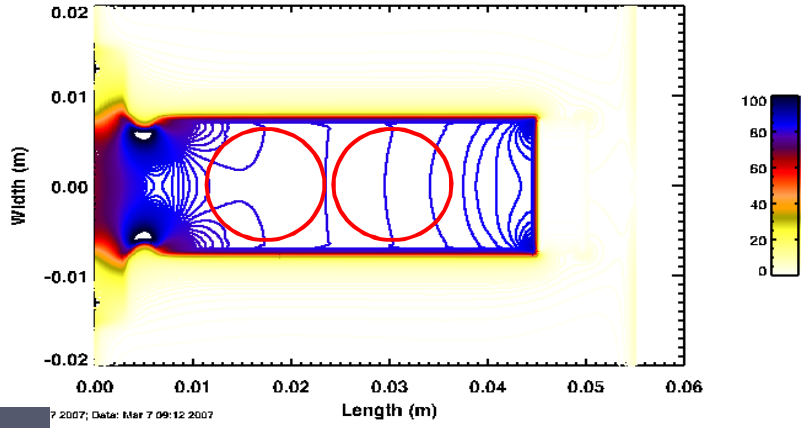
Simulation Results – Long Panel

notch size variation - R = 1.5mm, 1.0mm, 0.5mm and no notches

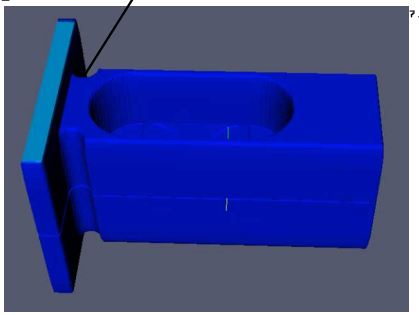
15mmx50mm panel, no notches, B at t=0.2µs



15mmx50mm panel, notches r=1.0mm, B at t=0.2µs

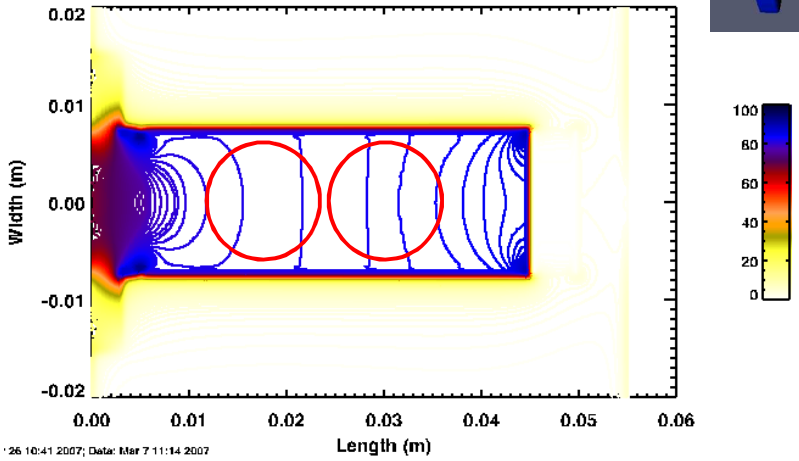


notch

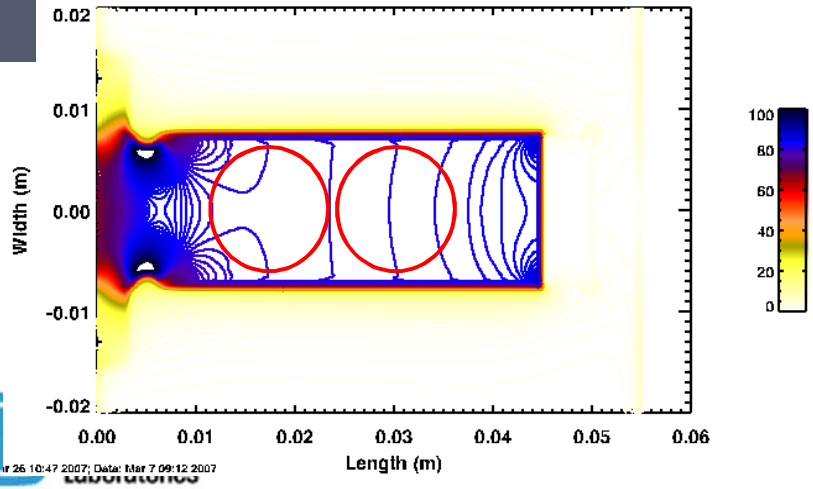


Resolution: ~0.5 % between levels

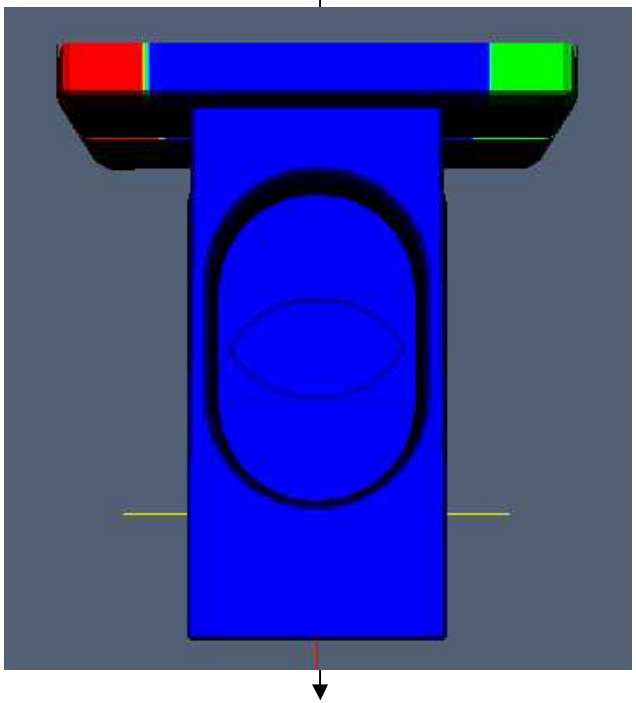
15mmx50mm panel, notches r=0.5mm, B at t=0.2µs

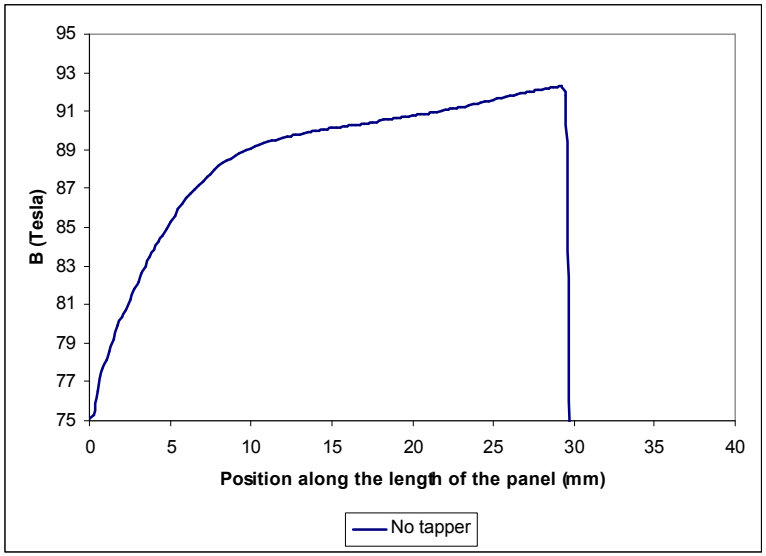


15mmx50mm panel, notches r=1.5mm, B at t=0.2µs

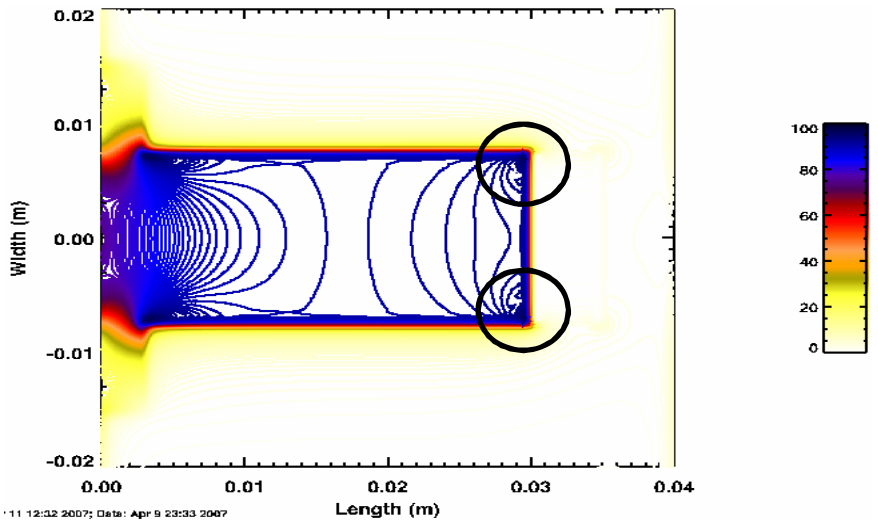


Current density non uniformity at the end of the panel





Problem: B at the edge of the contact is about 15% higher than in the center, causing B to increase by about 3% along the usable part of the panel → need to reduce/eliminate the hot spot at the end of the contact by modifying the contact area of the panel



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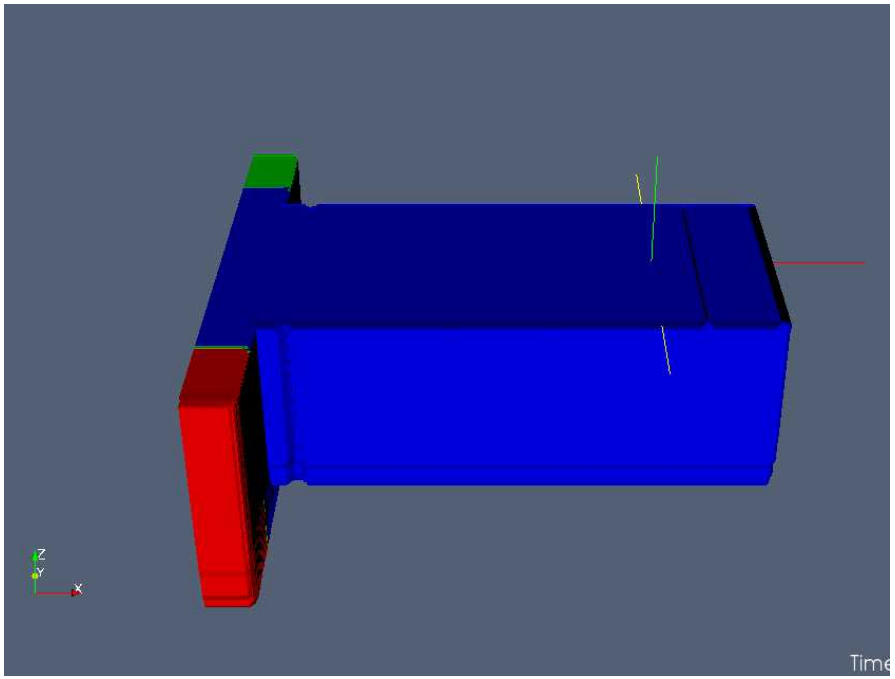
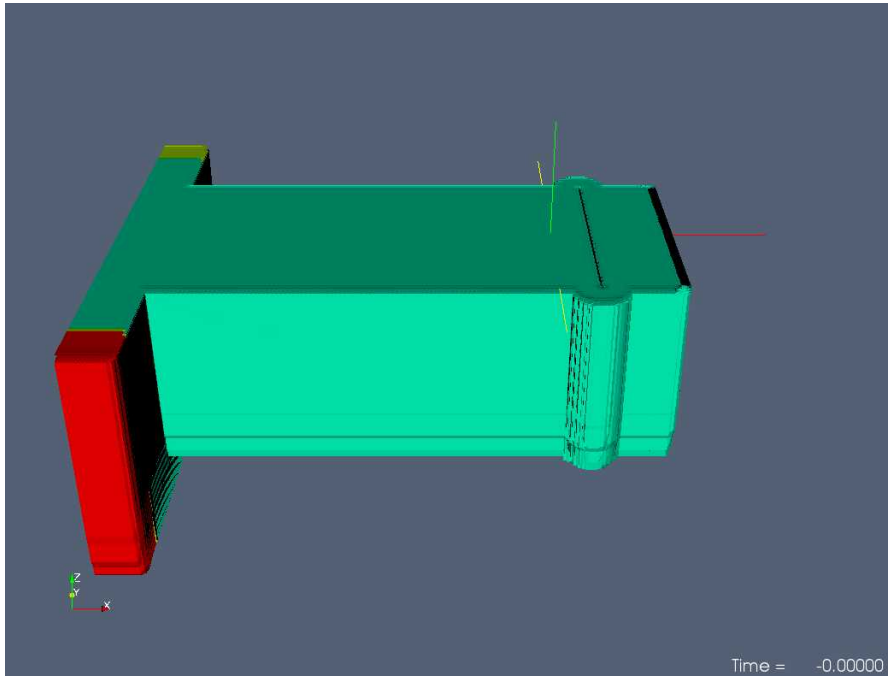
B (T) at the edge of the panel between the two panels. B is directly proportional to Jtot.

Proposed modification

Original panel



Modified panel



Bottom panel with contact. Contact does not show well because we are limited by the resolution of the simulation.

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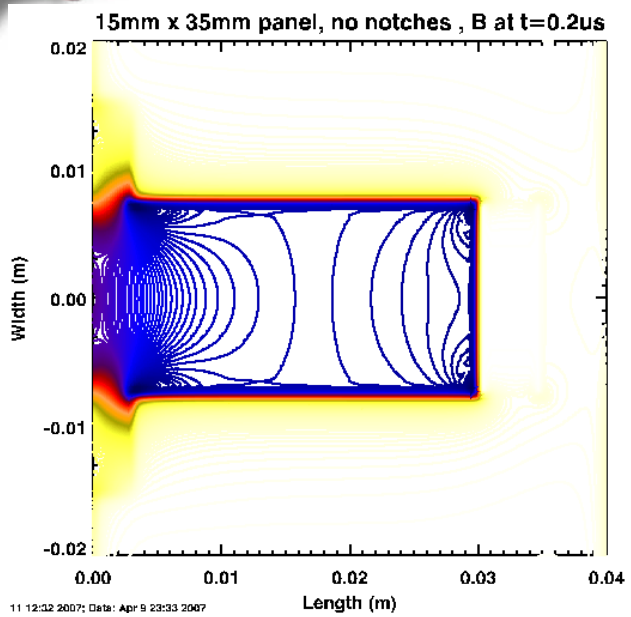
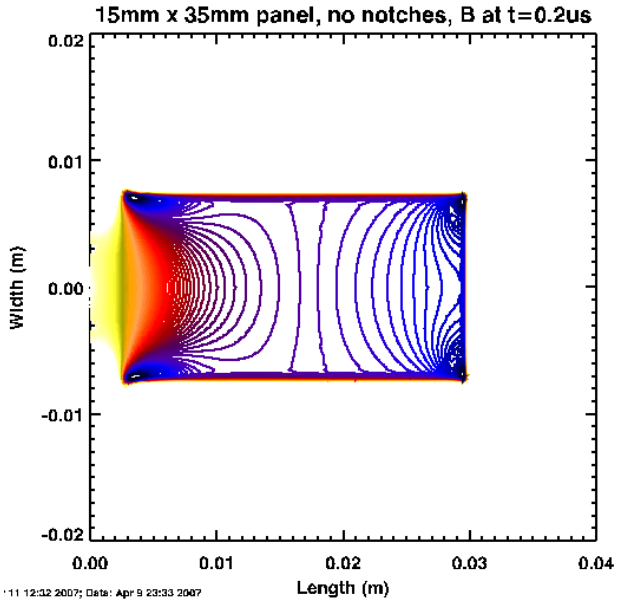
Preliminary Results

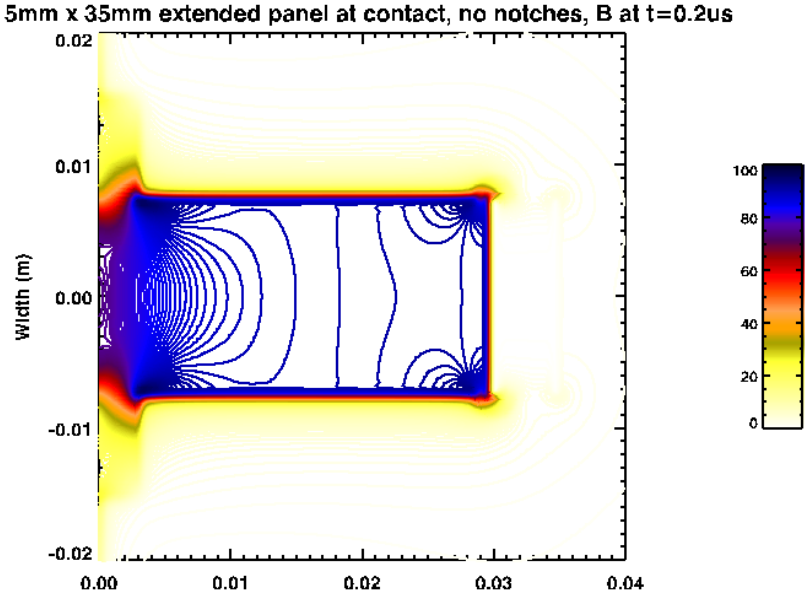
Original panel

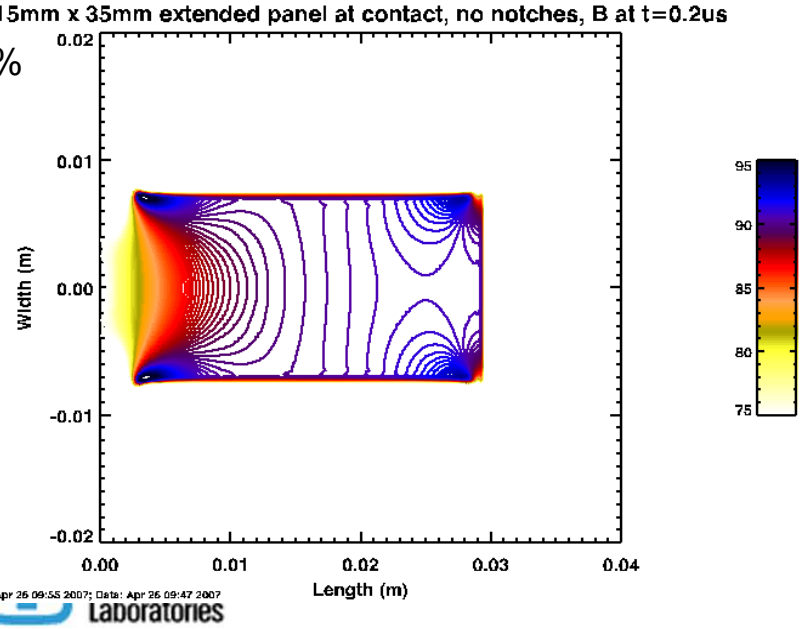




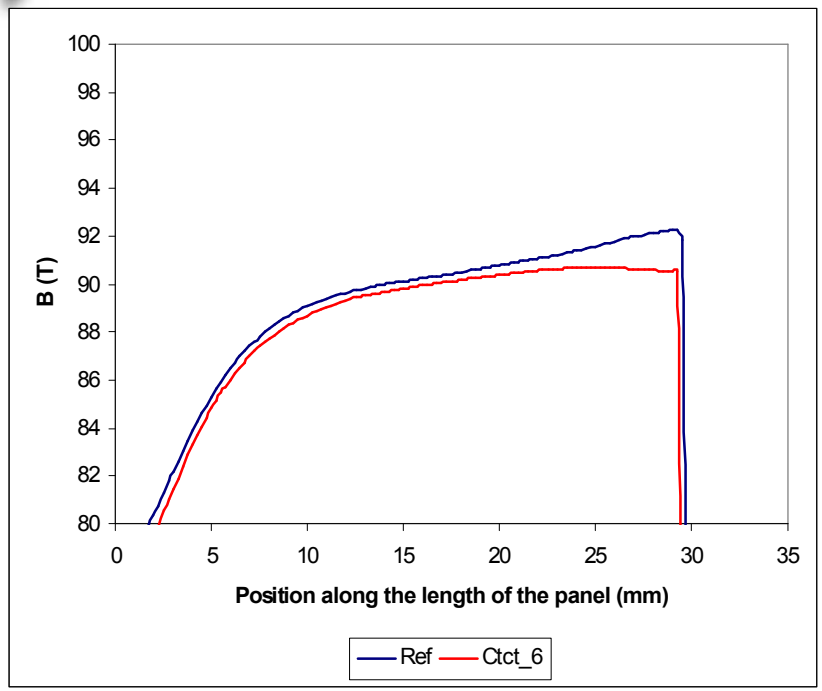
Resolution:
Top plots: 0.45 %
Bottom plots: 0.25%

Modified panel

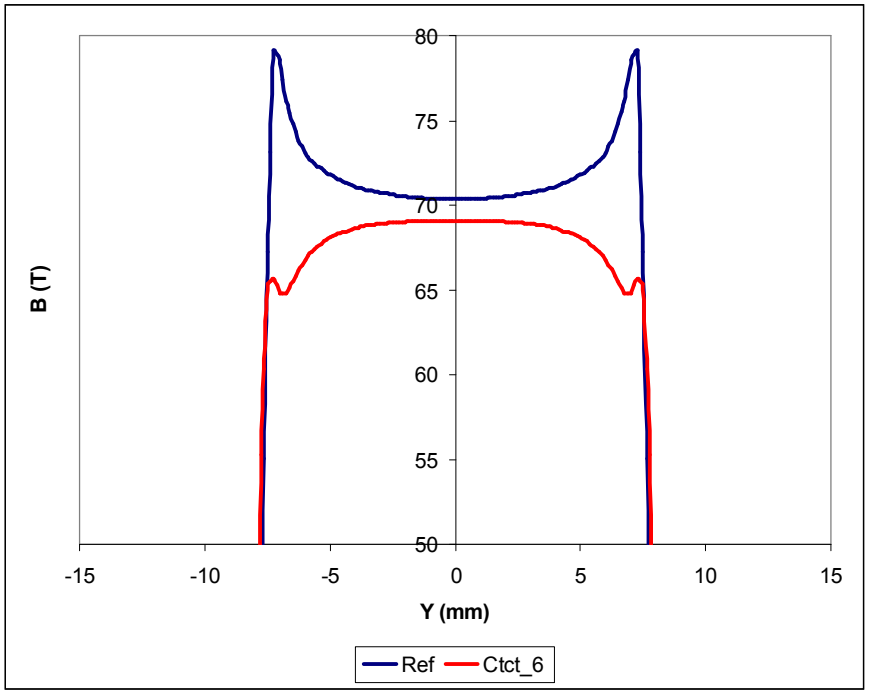




Preliminary Results



B at the edge of the panel between the two panels.



B along the width of the panel at the edge of the contact between the two panels.

An optimum solution should be in between those two cases

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Conclusions

- 3D simulations of VELOCE allow us to:
  - optimize the machine design (capacitor position) permitting an increase in the current delivered to the load and a decrease in the minimum rise time of the current
  - understand the current density distribution across the sample panel for a wide variety of panels thereby increasing the uniformity of the current and improving measurement accuracy
  - design the optimum panel for a specific sample minimizing the number of shots required for a given sample
- The simulations reproduced experimental free-surface velocities very well; resolution is the only limitation in 3D

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