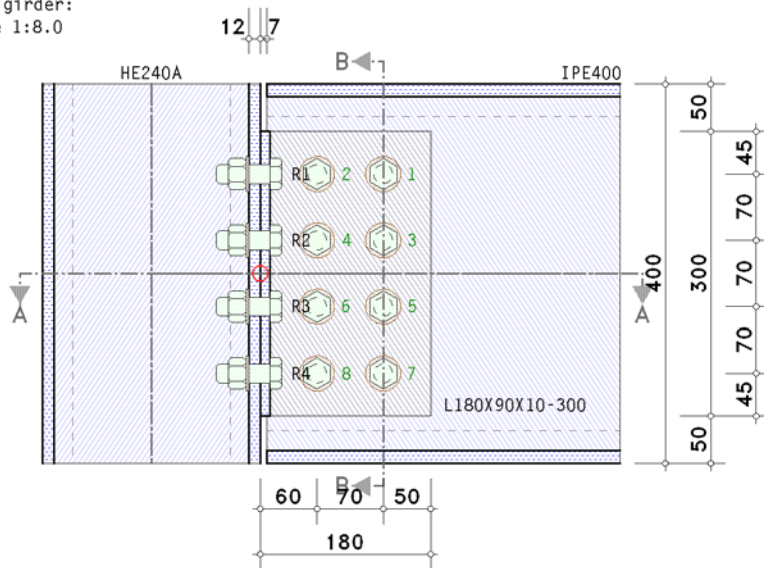


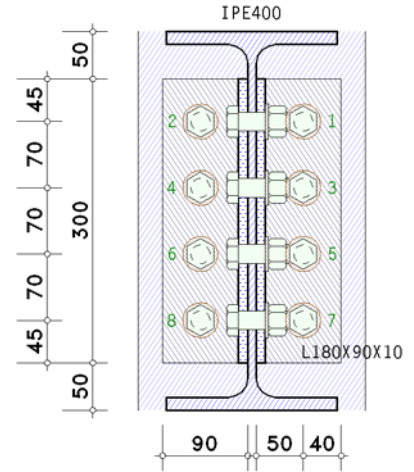
Simple Joint of Beams

EC 3-1-8 (12.10), NA: Deutschland

main girder:
scale 1:8.0



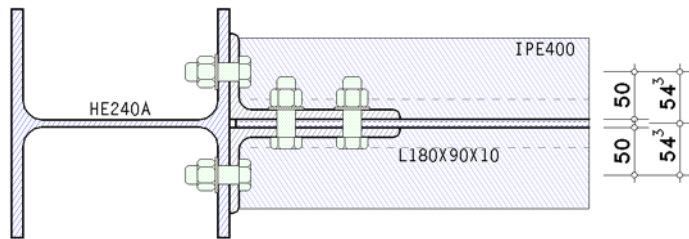
section B-B:



steel grade S 235

○ hinge

section A-A:



beam connection with two bolted angles, connected to the flange of the main girder

steel grade

steel grade S 235

bolts

bolt: bolt class 4.6,

dimensions:

shaft diameter $d = 20.0$ mm, clearance $\Delta d = 1.0$ mm $\Rightarrow$ hole diameter $d_0 = 21.0$ mm

gross cross-section area $A = 3.142$ cm²

tensile stress area $A_s = 2.450$ cm²

diameter of the bolt head (across flats dimension) $d_s = 30.0$ mm

diameter of the bolt head (across points dimension) $d_e = 32.95$ mm

thickness of the bolt head $t_k = 12.5$ mm

thickness of nut $t_m = 19.0$ mm

diameter of the plate under the bolt or the nut $d_p = 37.0$ mm

thickness of the plate under the bolt or the nut $t_p = 3.0$ mm

shear plane passes through the unthreaded portion of the bolt

geometry

main girder

section HE240A

supported beam

section IPE400

joint configuration

2 x angle: section L180X90X10

width of angles $b_a = 300.0$ mm

plate lengths: $h_o = 0.0$ mm, $\ddot{u}_o = 50.0$ mm ($h_u = 0.0$ mm, $\ddot{u}_u = 50.0$ mm), $s = 7.0$ mm

distances between bolts at main girder: $e_{z,0} = 45.0$ mm, $p_{z,1-2} = 70.0$ mm, $p_{z,2-3} = 70.0$ mm, $p_{z,3-4} = 70.0$ mm

$e_{x,0} = 40.0$ mm

distances between bolts at supported beam: $e_{z,0} = 45.0 \text{ mm}$, $p_{z,1-2} = 70.0 \text{ mm}$, $p_{z,2-3} = 70.0 \text{ mm}$, $p_{z,3-4} = 70.0 \text{ mm}$
 $e_{x,0} = 50.0 \text{ mm}$, $p_{x,1-2} = 70.0 \text{ mm}$

design resistance

verification of welds with the directional method

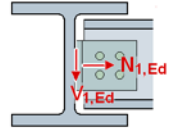
internal forces and moments

Lk 1: $V_{1,Ed} = 235.00 \text{ kN}$

partial safety factors for material

resistance of cross sections $\gamma_{M0} = 1.00$

resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$



Simple Joint of Beams

distance of bolt rows at main girder (right)

edge dist.:	$e_2 = 40.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_2 = 40.0 \text{ mm} < 4 \cdot t_{\min} + 40 \text{ mm} = 80.0 \text{ mm}$
pitch:	$p_2 = 108.6 \text{ mm} > 2.4 \cdot d_0 = 50.4 \text{ mm}$,	$p_2 = 108.6 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 140.0 \text{ mm}$
edge dist.:	$e_1 = 45.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_1 = 45.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 88.0 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 140.0 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 140.0 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 140.0 \text{ mm}$
edge dist.:	$e_1 = 45.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_1 = 45.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 88.0 \text{ mm}$

distance of bolt rows at supported beam (right)

edge dist.:	$e_2 = 50.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_2 = 50.0 \text{ mm} < 4 \cdot t_{\min} + 40 \text{ mm} = 74.4 \text{ mm}$
pitch:	$p_2 = 70.0 \text{ mm} > 2.4 \cdot d_0 = 50.4 \text{ mm}$,	$p_2 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 120.4 \text{ mm}$
edge dist.:	$e_2 = 53.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_2 = 53.0 \text{ mm} < 4 \cdot t_{\min} + 40 \text{ mm} = 74.4 \text{ mm}$
edge dist.:	$e_1 = 45.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_1 = 45.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 74.4 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 120.4 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 120.4 \text{ mm}$
pitch:	$p_1 = 70.0 \text{ mm} > 2.2 \cdot d_0 = 46.2 \text{ mm}$,	$p_1 = 70.0 \text{ mm} < \min(14 \cdot t_{\min}, 200 \text{ mm}) = 120.4 \text{ mm}$
edge dist.:	$e_1 = 45.0 \text{ mm} > 1.2 \cdot d_0 = 25.2 \text{ mm}$,	$e_1 = 45.0 \text{ mm} < 4 \cdot t_1 + 40 \text{ mm} = 74.4 \text{ mm}$

assumption: hinge is in the periphery to the flange of the main girder

Lk 1:

design values

transformation of member forces to the reference point (intersection point of beam axis')

$M_{1,Ed} = V_{j1,Ed} \cdot e_1 = -27.02 \text{ kNm}$, $e_1 = -115.0 \text{ mm}$

$V_{1,Ed} = V_{j1,Ed} = 235.00 \text{ kN}$

design resistance of the connection

angle leg at main girder:

compression by contact

dimensions of contact area $h_D = 20.0 \text{ mm}$, $b_D = 14.7 \text{ mm}$, compression force in contact area $D = 31.97 \text{ kN}$

check: $D / (A_D \cdot f_{yD}) = 0.463 < 1$ **ok.** $\Rightarrow$ compression by contact exists

calculation of the point section:

bolt 1 $T_{y,1} = 2.00 \text{ kN}$, $T_{z,1} = 29.38 \text{ kN}$, $T_1 = 29.44 \text{ kN}$

bolt 2 $T_{y,2} = 5.99 \text{ kN}$, $T_{z,2} = 29.38 \text{ kN}$, $T_2 = 29.98 \text{ kN}$

bolt 3 $T_{y,3} = 9.99 \text{ kN}$, $T_{z,3} = 29.38 \text{ kN}$, $T_3 = 31.03 \text{ kN}$

bolt 4 $T_{y,4} = 13.99 \text{ kN}$, $T_{z,4} = 29.38 \text{ kN}$, $T_4 = 32.54 \text{ kN}$

shear force resistance

bolts in shear:

$U_i = T_i / F_{v,Rd}$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 60.32 \text{ kN}$, $\alpha_v = 0.60$

bolt 1: $U_1 = 0.488$ $V_{Rd,1} = 481.4 \text{ kN}$

bolt 2: $U_2 = 0.497$ $V_{Rd,2} = 472.8 \text{ kN}$

bolt 3: $U_3 = 0.514$ $V_{Rd,3} = 456.8 \text{ kN}$

bolt 4: $U_4 = 0.539$ $V_{Rd,4} = 435.7 \text{ kN}$

design shear resistance total: $V_{Rd,1} = 435.7 \text{ kN}$

angle leg 2 with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}$, $U_{y,i} = T_{y,i} / F_{b,y,Rd}$, $U_i = \max(U_{z,i}, U_{y,i})$, $V_{Rd,i} = V_{1,Ed} / U_i$, $V_{Rd} = \min V_{Rd,i}$

bolt 1: $F_{b,z,1} = 102.86 \text{ kN}$ $F_{b,y,1} = 91.43 \text{ kN}$ $U_1 = 0.286$ $V_{Rd,1} = 822.9 \text{ kN}$

bolt 2:	$F_{b,z,2} = 124.00 \text{ kN}$	$F_{b,y,2} = 91.43 \text{ kN}$	$U_2 = 0.237$	$V_{Rd,2} = 992.0 \text{ kN}$
bolt 3:	$F_{b,z,3} = 124.00 \text{ kN}$	$F_{b,y,3} = 91.43 \text{ kN}$	$U_3 = 0.237$	$V_{Rd,3} = 992.0 \text{ kN}$
bolt 4:	$F_{b,z,4} = 102.86 \text{ kN}$	$F_{b,y,4} = 91.43 \text{ kN}$	$U_4 = 0.286$	$V_{Rd,4} = 822.9 \text{ kN}$
design bearing resistance total: $V_{Rd,2} = 822.9 \text{ kN}$				

beam flange with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}, U_{y,i} = T_{y,i} / F_{b,y,Rd}, U_i = \max(U_{z,i}, U_{y,i}), V_{Rd,i} = V_{1,Ed} / U_i, V_{Rd} = \min V_{Rd,i}$				
bolt 1:	$F_{b,z,1} = 148.80 \text{ kN}$	$F_{b,y,1} = 172.80 \text{ kN}$	$U_1 = 0.197$	$V_{Rd,1} = 1190.4 \text{ kN}$
bolt 2:	$F_{b,z,2} = 148.80 \text{ kN}$	$F_{b,y,2} = 172.80 \text{ kN}$	$U_2 = 0.197$	$V_{Rd,2} = 1190.4 \text{ kN}$
bolt 3:	$F_{b,z,3} = 148.80 \text{ kN}$	$F_{b,y,3} = 172.80 \text{ kN}$	$U_3 = 0.197$	$V_{Rd,3} = 1190.4 \text{ kN}$
bolt 4:	$F_{b,z,4} = 148.80 \text{ kN}$	$F_{b,y,4} = 172.80 \text{ kN}$	$U_4 = 0.197$	$V_{Rd,4} = 1190.4 \text{ kN}$
design bearing resistance total: $V_{Rd,3} = 1190.4 \text{ kN}$				

shear resistance: $\min V_{Rd,a2} = V_{Rd,1} = 435.7 \text{ kN}$

angle leg at supported beam:

calculation of the point section:

bolt 1	$T_{y,1} = 39.87 \text{ kN}, T_{z,1} = 16.09 \text{ kN}, T_1 = 42.99 \text{ kN}$
bolt 2	$T_{y,2} = 39.87 \text{ kN}, T_{z,2} = 42.66 \text{ kN}, T_2 = 58.39 \text{ kN}$
bolt 3	$T_{y,3} = 13.29 \text{ kN}, T_{z,3} = 16.09 \text{ kN}, T_3 = 20.87 \text{ kN}$
bolt 4	$T_{y,4} = 13.29 \text{ kN}, T_{z,4} = 42.66 \text{ kN}, T_4 = 44.69 \text{ kN}$
bolt 5	$T_{y,5} = -13.29 \text{ kN}, T_{z,5} = 16.09 \text{ kN}, T_5 = 20.87 \text{ kN}$
bolt 6	$T_{y,6} = -13.29 \text{ kN}, T_{z,6} = 42.66 \text{ kN}, T_6 = 44.69 \text{ kN}$
bolt 7	$T_{y,7} = -39.87 \text{ kN}, T_{z,7} = 16.09 \text{ kN}, T_7 = 42.99 \text{ kN}$
bolt 8	$T_{y,8} = -39.87 \text{ kN}, T_{z,8} = 42.66 \text{ kN}, T_8 = 58.39 \text{ kN}$

shear force resistance

bolts in shear:

$$U_i = T_i / (2 \cdot F_{v,Rd}), V_{Rd,i} = V_{1,Ed} / U_i, V_{Rd} = \min V_{Rd,i}$$

design shear resistance per shear plane: $F_{v,Rd} = \alpha_v \cdot f_{ub} \cdot A / \gamma_{M2} = 60.32 \text{ kN}, \alpha_v = 0.60$

bolt 1:	$U_1 = 0.356$	$V_{Rd,1} = 659.5 \text{ kN}$
bolt 2:	$U_2 = 0.484$	$V_{Rd,2} = 485.5 \text{ kN}$
bolt 3:	$U_3 = 0.173$	$V_{Rd,3} = 1358.7 \text{ kN}$
bolt 4:	$U_4 = 0.370$	$V_{Rd,4} = 634.4 \text{ kN}$
bolt 5:	$U_5 = 0.173$	$V_{Rd,5} = 1358.7 \text{ kN}$
bolt 6:	$U_6 = 0.370$	$V_{Rd,6} = 634.4 \text{ kN}$
bolt 7:	$U_7 = 0.356$	$V_{Rd,7} = 659.5 \text{ kN}$
bolt 8:	$U_8 = 0.484$	$V_{Rd,8} = 485.5 \text{ kN}$

design shear resistance total: $V_{Rd,1} = 485.5 \text{ kN}$

angle leg 1 with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}, U_{y,i} = T_{y,i} / F_{b,y,Rd}, U_i = \max(U_{z,i}, U_{y,i}), V_{Rd,i} = V_{1,Ed} / U_i, V_{Rd} = \min V_{Rd,i}$				
bolt 1:	$F_{b,z,1} = 102.86 \text{ kN}$	$F_{b,y,1} = 114.29 \text{ kN}$	$U_1 = 0.174$	$V_{Rd,1} = 1347.4 \text{ kN}$
bolt 2:	$F_{b,z,2} = 102.86 \text{ kN}$	$F_{b,y,2} = 114.29 \text{ kN}$	$U_2 = 0.207$	$V_{Rd,2} = 1133.1 \text{ kN}$
bolt 3:	$F_{b,z,3} = 124.00 \text{ kN}$	$F_{b,y,3} = 114.29 \text{ kN}$	$U_3 = 0.065$	$V_{Rd,3} = 3623.0 \text{ kN}$
bolt 4:	$F_{b,z,4} = 124.00 \text{ kN}$	$F_{b,y,4} = 114.29 \text{ kN}$	$U_4 = 0.172$	$V_{Rd,4} = 1366.0 \text{ kN}$
bolt 5:	$F_{b,z,5} = 124.00 \text{ kN}$	$F_{b,y,5} = 114.29 \text{ kN}$	$U_5 = 0.065$	$V_{Rd,5} = 3623.0 \text{ kN}$
bolt 6:	$F_{b,z,6} = 124.00 \text{ kN}$	$F_{b,y,6} = 114.29 \text{ kN}$	$U_6 = 0.172$	$V_{Rd,6} = 1366.0 \text{ kN}$
bolt 7:	$F_{b,z,7} = 102.86 \text{ kN}$	$F_{b,y,7} = 114.29 \text{ kN}$	$U_7 = 0.174$	$V_{Rd,7} = 1347.4 \text{ kN}$
bolt 8:	$F_{b,z,8} = 102.86 \text{ kN}$	$F_{b,y,8} = 114.29 \text{ kN}$	$U_8 = 0.207$	$V_{Rd,8} = 1133.1 \text{ kN}$
design bearing resistance total: $V_{Rd,2} = 1133.1 \text{ kN}$				

angle leg 1 in tension and shear (shear block):

shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 373.69 \text{ kN}$

shear resistance total: $V_{Rd,3} = 373.7 \text{ kN}$

angle leg 1 in bending and shear:

$(A_{f,net} \cdot 0.9 \cdot f_u) / \gamma_{M2} = 279.9 \text{ kN} < (A_f \cdot f_y) / \gamma_{M0} = 352.5 \text{ kN} \Rightarrow$ der deduction of holes is respected.

shear resistance $V_{Rd} = f_y / \gamma_{M0} / ((b' / W_{el})^2 + 3 \cdot (1/A)^2)^{1/2} = 201.26 \text{ kN}$

shear resistance total: $V_{Rd,4} = 2 \cdot 201.26 = 402.5 \text{ kN}$

beam web with bearing resistance:

$U_{z,i} = T_{z,i} / F_{b,z,Rd}, U_{y,i} = T_{y,i} / F_{b,y,Rd}, U_i = \max(U_{z,i}, U_{y,i}), V_{Rd,i} = V_{1,Ed} / U_i, V_{Rd} = \min V_{Rd,i}$				
bolt 1:	$F_{b,z,1} = 106.64 \text{ kN}$	$F_{b,y,1} = 104.18 \text{ kN}$	$U_1 = 0.383$	$V_{Rd,1} = 614.1 \text{ kN}$
bolt 2:	$F_{b,z,2} = 106.64 \text{ kN}$	$F_{b,y,2} = 104.18 \text{ kN}$	$U_2 = 0.400$	$V_{Rd,2} = 587.4 \text{ kN}$
bolt 3:	$F_{b,z,3} = 106.64 \text{ kN}$	$F_{b,y,3} = 104.18 \text{ kN}$	$U_3 = 0.151$	$V_{Rd,3} = 1557.9 \text{ kN}$
bolt 4:	$F_{b,z,4} = 106.64 \text{ kN}$	$F_{b,y,4} = 104.18 \text{ kN}$	$U_4 = 0.400$	$V_{Rd,4} = 587.4 \text{ kN}$
bolt 5:	$F_{b,z,5} = 106.64 \text{ kN}$	$F_{b,y,5} = 104.18 \text{ kN}$	$U_5 = 0.151$	$V_{Rd,5} = 1557.9 \text{ kN}$
bolt 6:	$F_{b,z,6} = 106.64 \text{ kN}$	$F_{b,y,6} = 104.18 \text{ kN}$	$U_6 = 0.400$	$V_{Rd,6} = 587.4 \text{ kN}$
bolt 7:	$F_{b,z,7} = 106.64 \text{ kN}$	$F_{b,y,7} = 104.18 \text{ kN}$	$U_7 = 0.383$	$V_{Rd,7} = 614.1 \text{ kN}$
bolt 8:	$F_{b,z,8} = 106.64 \text{ kN}$	$F_{b,y,8} = 104.18 \text{ kN}$	$U_8 = 0.400$	$V_{Rd,8} = 587.4 \text{ kN}$

design bearing resistance total: $V_{Rd,5} = 587.4 \text{ kN}$

beam web in tension and shear (shear block):

shear resistance $V_{eff,Rd} = (0.5 \cdot A_{nt} \cdot f_u) / \gamma_{M2} + (A_{nv} \cdot f_y / 3^{1/3}) / \gamma_{M0} = 383.43 \text{ kN}$

shear resistance total: $V_{Rd,6} = 383.4 \text{ kN}$

shear resistance: $\min V_{Rd,a1} = V_{Rd,3} = 373.7 \text{ kN}$

design resistance: $\min V_{Rd} = 373.7 \text{ kN}$

verification of the connection

$V_{Ed} = 235.0 \text{ kN}$: $V_{Ed} / \min V_{Rd} = 0.629 < 1$ **ok.**

verification result

maximum utilization: $\max U = 0.629 < 1$ **ok.**

Final Result

maximum utilization: design resistance $\max U = 0.629 < 1$ **ok.**

verification succeeded

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;

Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010

DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;

Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010

DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2010

DIN EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-8: Bemessung von Anschlüssen;

Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010

DIN EN 1993-1-8/NA, Nationaler Anhang zur DIN EN 1993-1-8, Ausgabe Dezember 2010

ECCS Document No. 126: European Recommendations for the Design of Simple Joints in Steel Structures.

ECCS TC10 - Structural Connections, 2009. J.P. Jaspart, J.F. Démonceau, S. Renkin, M.L. Guillaume